

SESAR Innovation Days 2018

Posters Abstracts

Advances in the Observations for natural airborne aviation related hazards in the frame of EUNADICS-AV project

An Early Warning System for multiple airborne hazards to aviation in the EUNADICS-AV project

EvoATM: an evolutionary agent-based modelling Open Demonstrator for change design and impact assessment in ATM

Solutions for Increased General Aviation and Rotorcraft Airport Accessibility - The GRADE Project

An Approach to Define Adverse Weather Zones Based on the Flight Management Performed by Pilots in Convective Weather Events

RADIAN Project

Vertical Flight Trajectory Efficiency, a quantitative study on the effects and causes of climb restrictions for flights departing Amsterdam Airport Schiphol

Contemporary wildlife risk challenges and habitat management in the vicinity of airports

pyBADA: Easy BADA integration in python for rapid prototyping

Data driven insight in aircraft taxi time

Aviation collaborative research

PFV : ENAC's flying testbed A new platform for Aeronautical and Air Traffic Control applied research

CLear Air Situation for uas

Learning Air Traffic Controller Strategies with Real-Time Neural and Physiological Feedback

ADAPT - Advanced Prediction Models for Trajectory-Based Operations (TBO)

Route charging per airport-pair in Europe - How to come up with unit rates? Impacts of traffic distribution over charging zones

Augmented Reality (AR) for ATCO supervisors

No More Surprises: Stand Assignment Algorithm with Likelihood of Turnaround Time Deviation

Technical exhibit and demonstration of DataBeacon: The Secure AI Multi-Sided Platform for Aviation

Deep Reinforcement Learning for Multiple Drones Air Traffic Management

EMPHASIS (EMPowering Heterogeneous Aviation through cellular SignalS) Project Overview

Building a safe and socially acceptable concept of operation for drones flying at the very low level

The Resilient Properties of Multiple Remote Tower Operations: LFV RE5

An Empiric Stress Test Validation for Multi Remote Tower Safety Assessment

Advances in ATM simulation by using global flight simulation framework NAVSIM

An automated algorithm for the assessment of drowsiness based on a single EEG channel: validation results and method - 3

Application of the paradigm of nets-within-nets to air traffic management

What if controllers would no longer be limited by what the human eye can see out of the tower windows? The RETINA project

Advances in the Observations for Natural Airborne Aviation-related Hazards in the Frame of the EUNADICS-AV Project

Lucia Mona, Nikolaus Papagiannopoulos, Francesco Marchese, Alfredo Falconieri
Institute of Methodologies for Environmental Analysis
IMAA- CNR
Tito Scalo (PZ), Italy
lucia.mona@imaa.cnr.it,

Piet Stammes, Jos de Laat, Arnoud Apituley
Koninkrijk Nederlands Meteorologisch Instituut KNMI
De Bilt, Netherlands

Heikki Lihavainen, Jussi Paatero, Timo Virtanen
Finish Meteorological Institute - FMI
Finland

Nicolas Theys
Support to Aviation Control Service BIRA-IASB
Brussels, Belgium

Alexander Haefele, Rolf Rufenacht, Maxime Hervé
Eidgenössisches Department des Innern - MeteoSwiss
Switzerland

Abstract— The vulnerability of the European aviation system to the airborne hazards was evident during the Eyjafjallajökull eruption in 2010. Many observations were available at European level both at the ground and from space, but they were not efficient provided to relevant actors. The observational component of the H-2020 project EUNADICS-AV (“European Natural Disaster Coordination and Information System for Aviation”) aims to make more accessible, visible and used the existing products and to foster tailored product development. These products availability and injection in the EUNADICS-AV system are the base for efficiently improve the European resilience to the airborne hazards for the aviation. New products nowadays available and particularly suited for airborne hazard alerting and monitoring are presented, together with specific tailored products designed for replying to user needs and recommendations.

Keywords—component; new generation observations; tailored products; air traffic; natural hazards

I. INTRODUCTION

The observational component of the EUNADICS project aims to provide integrated and advanced data sets of atmospheric constituents relevant to resilience of atmospheric hazards. The focus is on atmospheric aerosols with trace gases used as indicators, for desert dust storms, forest fires and volcano eruptions and nuclear incidents. The advancement on the observational and integrated products are designed on the base of the recommendations collected within the project by relevant stakeholders in terms of user requirements and data needs. Observational datasets (satellite, ground base and airborne remote sensing and in-situ measurements) are the base for the development of an Early Warning System and for the assimilation into dispersion models.

II. RESULTS

During the first phase of the EUNADICS-AV project, a review of existing observations for airborne hazard monitoring

and a collection of user recommendations have been done. These activities allowed to prioritize tailored product development and to maximize the impact of data availability.

These have been identified as main priorities:

- tailored products that could (possibly) improve situational awareness [higher resolution, RT provision, global coverage, low and characterized uncertainty]
- satellite/airborne visualization of hazard identification
- visualization of lidar imagery for volcanic ash identification

Among the novel observations available within EUNADICS-AV there are the aerosol and trace gas observations at much improved spatial resolution ($3.5 \times 7 \text{ km}^2$) provided by TROPOMI on board of the Copernicus Sentinel-5P polar satellite. During its first months of activities TROPOMI already showed its high potential in detecting and monitoring with high definition desert dust, volcanic plume and forest fires (Fig. 1).

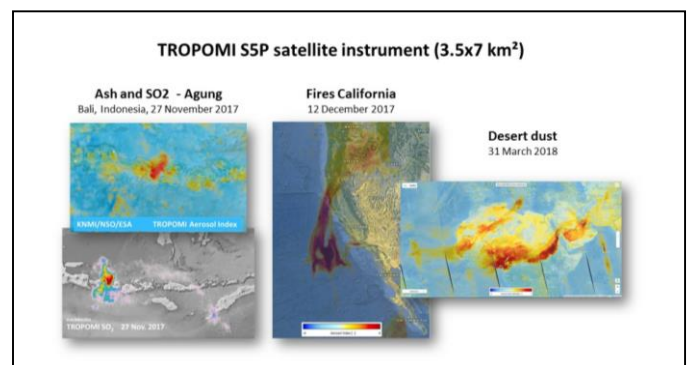


Figure 1. Example of the observations for volcanic eruption, forest fires and desert dust storm as captured from the novel ESA TROPOMI S5P satellite instrument.

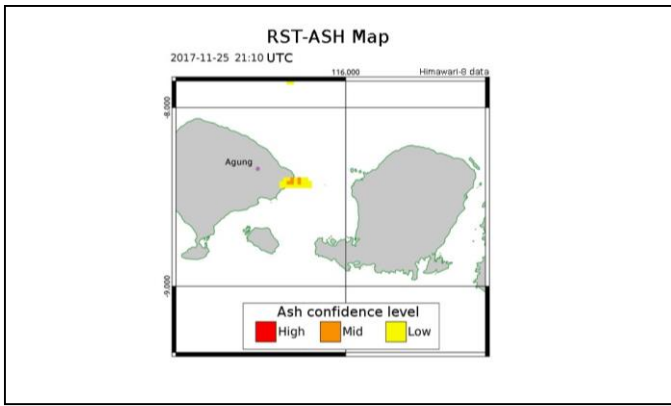


Figure 2. Example of a tailored satellite products for the aviation hazards. Figure reports the ash identification made by the RST-ASH algorithm using Himawari-8 geostationary data.

Novel tailored algorithms for imagers on the geostationary satellites, like the one from Marchese et al. (2018), have been developed for a more efficient identification of ash clouds, providing also a level of uncertainty based on stand-alone procedure. This algorithm is the result of a tailoring process of a previously developed algorithm and it is able to identify in NRT the regions affected by airborne ash (Fig.2).

All these new products are now under validation through ground/air based measurements.

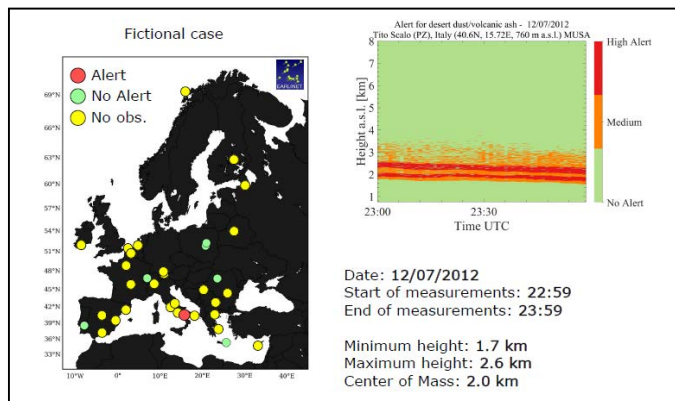


Figure 3. Tailored GB product under development from ACTRIS/EARLINET network for the NRT identification of desert dust/ash observations

Finally based on the VAAC requests, quicklook of the lidar signals acquired at European scale by ACTRIS/EARLINET and similar products available from E-profile, the operational low power lidar/ceilometer network, will be made available through the EUNADICS-AV portal. Additionally, a new tailored ACTRIS/EARLINET products is under investigation for the NRT identification of dust/ash cloud (Fig. 3), to be made available through EUNADICS_AV and ingested in the Early Warning System.

As next step, cross-calibration and validation of relevant data products provided by different platforms is now in progress. In particular, ceilometer aerosol products are compared to ACTRIS/EARLINET data for the quantification of products uncertainty. Additionally, the new tailored products are validated against reference observations for selected case studies. The provision of such uncertainty is essential for the assimilation/evaluation of dispersion models and for the use of such kind of observations in the operational decision chain.

ACKNOWLEDGMENT

The research leading to the results has received funding from the European Union's Horizon 2020 Research and Innovation Programme, under Grant Agreement no 723986.

REFERENCES

- [1] Marchese, F.; Falconieri, A.; Pergola, N.; Tramutoli, V. Monitoring the Agung (Indonesia) Ash Plume of November 2017 by Means of Infrared Himawari 8 Data. *Remote Sens.* 2018, 10, 919.
- [2] Papagiannopoulos, N., Mona, L., Amodeo, A., D'Amico, G., Gumà Claramunt, P., Pappalardo, G., Alados-Arboledas, L., Guerrero-Rascado, J. L., Amiridis, V., Apituley, A., Baars, H., Schwarz, A., Wandinger, U., Binietoglou, I., Nicolae, D., Bortoli, D., Comerón, A., Rodríguez-Gómez, A., Sicard, M., Kokkalis, P., Papayannis, A., and Wiegner, M.: An automatic observation-based typing method for EARLINET, *Atmos. Chem. Phys. Discuss.*, <https://doi.org/10.5194/acp-2018-427>, in review, 2018.
- [3] Stammes, P.; Sneep, M.; Wang, P.; Gijssbert T., L.; de Graaf, M.; Kooreman, M.; ter Linden, M.; Pepijn V., J., A sharper view of clouds and aerosols with TROPOMI, *Geophysical Research Abstracts*, Vol. 20, EGU2018-12078, 2018, EGU General Assembly 2018.

An Early Warning System for Multiple Airborne Hazards to Aviation in the EUNADICS-AV Project

Hugues Brenot, Nicolas Theys
SACS / BIRA-IASB
Brussels, Belgium
brenot@aeronomie.be

Lieven Clarisse, Daniel R. Hurtmans
ULB
Brussels, Belgium

Lucia Mona, Nikolaos Papagiannopoulos
IMAA / CNR
Potenza, Italy

Margarita Vázquez-Navarro, Pascal Hedelt
DLR
Oberpfaffenhofen, Germany

Juhani Lahtinen, Tuomas Peltonen
STUK
Helsinki, Finland

Delia Arnold-Arias, Gerhard Wotawa
ZAMG
Vienna, Austria

Michelle M. Parks, Guðrún N. Petersen
IMO
Reykjavík, Iceland

Mauro Coltelli, Simona Scollo
INGV
Catania, Italy

Timo Virtanen, Mikhail Sofiev
FMI
Helsinki, Finland

Klaus Sievers
KSAW
Lenggries, Germany

and WP5 team of EUNADICS-AV project

Abstract— The continuously developing aviation sector is key in Europe but is vulnerable to various airborne hazards. In case of an exceptional event, basic information has to reach key actors efficiently and rapidly. The observational component of the H-2020 project EUNADICS-AV (“European Natural Disaster Coordination and Information System for Aviation”) is used to build an Early Warning System. The purpose of this system is to use data products from satellite, ground-based and in situ platforms to produce alerts, satisfying the requirement of users. Our prototype system is designed for triggering model forecasts. Alerts are delivered to the EUNADICS-AV users and to interested stakeholders who can contact us to get them. With near real-time products derived from the available monitoring networks (from EUNADICS-AV partners and other networks), appropriate information from notification of the hazardous event to the response and remediation phase perspectives are provided via short term alerts sent a few hours or even less after the start of the airborne hazard.

Keywords—Early warning system; notification of airborne hazards

I. INTRODUCTION

The EUNADICS-AV Early Warning System (EWS) addresses the need for an early notification system for multi-hazards to aviation about volcanic ash and sulphur dioxide (SO₂) plumes, sandstorms, dust clouds, aerosols produced from forest fires, and radioactive plumes. The objective of EUNADICS-AV EWS notifications is threefold:

- 1) to enhance situation awareness in case of crisis situation,
- 2) to trigger atmospheric transport and dispersion models of forecasts/analyses,
- 3) to facilitate the transfer of required relevant information to end-users.

Based on a review of the user requirements, external reports and recommendations and the inventory of available observational data, a global multi-sensors warning system concept is proposed with the objective of showing the added-value of integrating near real-time (NRT) harmonised aerosols/radionuclide data observations for crises cases affecting European air space.

II. EARLY WARNING SYTEM CONCEPT

First, The EWS concept relies on the existing Support to Aviation Control Service (<http://sacs.aeronomic.be> – SACS) developed by BIRA-IASB for volcanic crises. SACS is based on NRT data for volcanic ash and SO₂ [1] from a constellation of polar-orbiting satellite operational missions (Fig. 1).



Figure 1. Constellation of satellite sensors used in SACS.

Satellite images and email notifications products are provided to interested parties. The EUNADICS-AV EWS tackles multiple hazards (volcanic eruptions, fires, sand storms and radionucleides) and expands the existing SACS to:

- improve the discrimination between volcanic ash and other types of aerosols or meteorological clouds,
- determine plume heights (ash and SO₂), with information given at flight levels,
- retrieve volcanic ash mass loadings,
- include high temporal resolution measurements from geostationary platform (SEVIRI),
- include polar orbiting measurements with better spatial resolution (Sentinel 5 Precursor),
- expand the system with key measurements from the ground notably using lidar and ceilometers measurements, as well as near-source parameters from volcanic observatories.

The EUNADICS-AV EWS is closely linked to the EUNADICS-AV data portal with improved data visualisation. The satellite

and ground-based products in EWS provides vital information on hazards type, aerosols concentrations and plume location at high resolution (see example is in Fig. 2).

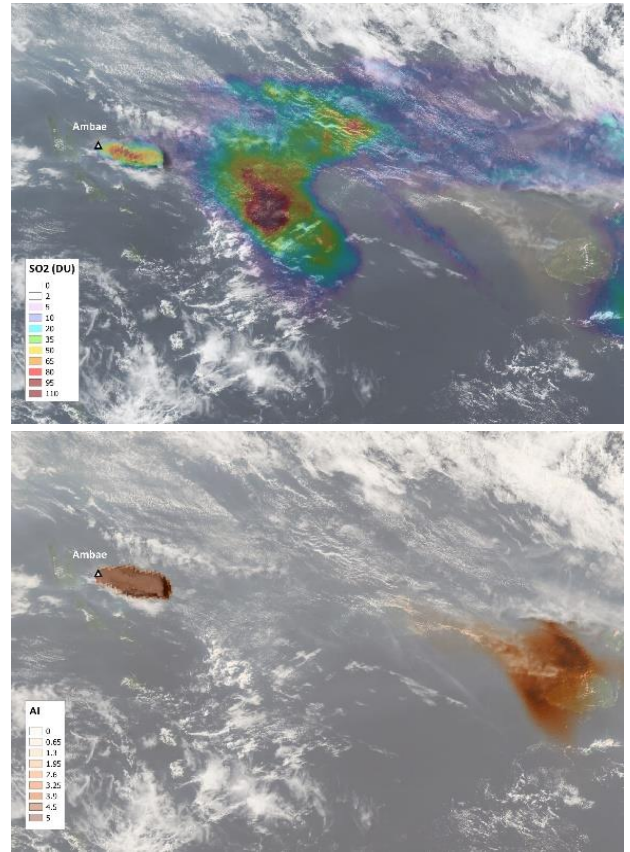


Figure 2. TROPOMI/Sentinel-5 Precursor SO₂ column and Aerosol index products for the eruption of Ambae on July 27, 2018.

Alerting products are also developed with email notifications (which include event IDs, links to imagery products and data alert products in NetCDF format, links to notification maps for ground-based measurements and links to the visualisation platform of EUNADICS data portal). A thorough description of the EWS definition and design can be found on EUNADICS-AV website (www.eunadics.eu).

ACKNOWLEDGMENT

The research leading to the results has received funding from the European Union's Horizon 2020 Research and Innovation Programme, under Grant Agreement no 723986.

REFERENCES

- [1] Brenot, H., Theys, N., Clarisse, L., van Geffen, J., van Gent, J., Van Roozendaal, M., van der A, R., Hurtmans, D., Coheur, P.-F., Clerbaux, C., Valks, P., Hedelt, P., Prata, F., Rason, O., Sievers, K., and Zehner, C., "Support to Aviation Control Service (SACS): an online service for near-real-time satellite monitoring of volcanic plumes," *Nat. Hazards Earth Syst. Sci.*, vol. 14, pp. 1099–1123, 2014.

EvoATM: An Evolutionary Agent-based Modelling Open Demonstrator for Change Design and Impact Assessment in ATM

A novel cost-effective platform to support the achievement of ATM performance targets through strategic thinking.

Gabriella Gigante, Domenico
Pascarella
CIRA Italian Aerospace Research
Centre
Capua, Italy
g.gigante@cira.it
d.pascarella@cira.it

Marta Sánchez Cidoncha
CRIDA Centro De Referencia
Investigacion Desarrollo e
Innovacion ATM
Madrid, Spain
mscidoncha@e-crida.enaire.es

Miquel Angel Piera
Universitat Autònoma De Barcelona
Barcelona, Spain
miquelangel.piera@uab.cat

Gabriella Duca, Mario Ciaburri
ISSNOVA Institute for Sustainable
Society and Innovation
Naples, Italy
duca@issnova.eu
ciaburri@issnova.eu

Luiz Manuel Braga Campos
PEDECE Projectos,
Empreendimentos, Desenvolvimento
e Equipamentos Científicos e De
Engenharia
Lisboa, Portugal
luiz.campos@tecnico.ulisboa.pt

Jose Luis Muñoz Gamarra
ASLOGIC
Barcelona, Spain
jlmunoz@aslogic.es

Abstract—EvoATM project is aimed at building a framework to better understand and model how architectural and design choices influence the ATM system and its behaviours, and vice versa how the expected ATM overall performances drive the innovation design choices. The project is modelling a specific part of ATM system, the Direct Route and Free Route environment, combining the agent based paradigms with evolutionary computing. The project outcome will be a solver which finds an optimal tuning of the design of new/modified ATM components to accomplish the expected performances. A sensitivity analysis strategy will be adopted in order to understand the influence of ATM components parameters on the behaviours at component performances level (behaviours of other components) and at whole system performances level within the test case environment. Finally, the framework is going to be tested by using known scenarios and quantitative indicators to validate its effectiveness in terms of change impact assessment, support to design and support to strategic thinking.

Air Traffic Management; Change Impact Assessment; Evolutionary Computing; Agent-Based Modelling; Open Demonstrator

I. INTRODUCTION

The increasing importance of collaborative decision-making processes in the Air Traffic Management (ATM) requires new modelling approaches aiming to emphasize its complex socio-technical dimensions [1]; in this view EvoATM project is integrating knowledge in ATM modelling and simulation with Agent-based Evolutionary computing, in order to build a model representing the whole of ATM system components and their

reciprocal interactions and effects. EvoATM model and platform are based on the following design approach:

- application of an agent-based modelling paradigm to represent the components of a sample part of the whole ATM environment, the services they provide, and their interdependencies (the test case environment is the Direct Route and the Free Route (FR) one);
- set-up of the proper performance indicators at system level and at component level for each modelled ATM technical and human component;
- definition and application of an analysis paradigm in order to perform change impact assessment and to support the strategic thinking, intended as the decision process to assess which part of the ATM system would need of a modification in order to match target performance levels, also adopting an evolutionary approach;
- drafting of a set of methodological guidelines in order to extend the experimented framework to any generic section of the ATM system.

II. EVOATM OPEN DEMONSTRATOR FEATURES

One of the key issues identified in the European ATM Master Plan [1] is recognising human actors as integral to the overall ATM system, and as the most critical source of its performance, safety and resilience. EvoATM modelling platform is based on a scenario approach and includes a model of the socio-technical

complexity of ATM environment interrelating cognitive aspects, social aspects, and technical aspects [2]. By using the agent-based paradigm for the proper integration of technical and human aspects, the EvoATM model is expected to be able to catch and represent:

- the aspects of human behaviours;
- the behaviours of technical components that are integrated in the reference system;
- the execution of the procedures that are applied by the involved actors;
- the interrelations amongst the involved actors;
- the description of the operative environment.

An early EvoATM result is the achievement of a unique modelling formalism taking advantages from multiple combined formalisms to address the EvoATM test case environment. A further step of the project concerns the verification of the plausibility of the EvoATM model with regard of the test case environment, this step allows to validate the EvoATM approach to modeling paradigm. In parallel, the identification of the evolutionary algorithm best fitting the EvoATM formalism will allow to deliver the Open Demonstrator component enabling the support to design feature. Finally, at the end of the project a comprehensive validation activity will be carried out in order to cope the goal of the EvoATM platform to support the strategic thinking and change impact assessment in the test case environment.

Any assessment provided by EvoATM platform will be evaluated in quantitative terms by means of KPIs, which have been selected in order to measure all the relevant performance dimensions for the test case environment [3]. The performance assessment of the test case is performed by means of specific metrics related:

- on one side to the performance of the modelled agents and systems and their interrelations (Agent-Based Metrics), and;
- on the other side to the performance of the executed trajectories according to the projection of outcomes of the actions of agents and systems (Trajectory Related PMs).

Both type of metrics are particular to the en-route spatial context since represented agents (human and technical) and system interrelations correspond to en-route operating concept. According the desired performance levels, EvoATM platform is expected to support (i) the identification of constraints to assure the requested performance level, (ii) the representation of the change by the modelling paradigm (e.g., in terms of a new or modified component, a new procedure, a new set of behaviours, etc.), (iii) the fine tuning of the changed models to comply with the required performance.

Combining the agent-based paradigm with a multi-objective evolutionary computing approach allows to define a solver which identifies an optimal tuning of the design of new/modified agents, corresponding to new/modified ATM components, to match the expected performances. In particular, this approach allows to explore the configuration space looking for Pareto-optimal solutions, without violating any constraint due to ATM-related specifications, while significantly reducing the time to converge to an optimal configuration. The

combination of the agent-based paradigm with sensitivity analysis strategies allows to understand the influence of components parameters on the behaviours at component performances level (behaviours of other components) and at system performances level.

III. EVOATM EXPECTED RESULTS IN THE VIEW OF ATM INNOVATION PROCESS

The EvoATM Open Demonstrator will quantify the impacts, in terms of variation of performance indicators, of the modelled solutions to qualitatively and quantitatively assess the addressed models in key performance areas such as safety, capacity, workload, cost-efficiency of ATM operations. The Open Demonstrator will support further developments and integration of the models of new or modified components or new procedures providing, at the same time, all required means to evaluate new concepts in mentioned Key Performance Areas. This refers to the possibility of running any type of scenario, not just EATMA-aligned ones, thanks to both the chosen modelling paradigm and the methodological guideline, specifically delivered for the Open Demonstration wider applicability.

The performance indicators will also allow the aggregation of quantitative measurements of different levels of granularity, such as global (i.e., for the behaviour of the overall ATM system or for a composite section or for a regional zone) versus local (i.e., for the single components). Moreover, when a modification is upgraded in the model, its potential impact can be measured and verified for its effectiveness and also for any possible regression of the system; new unwilling interdependencies could be introduced and quickly detected by the EvoATM analysis paradigm.

Features of EvoATM Open Demonstrator match with some key topics of the European ATM Master Plan, that highlights the ambition in providing the necessary technical system changes at reduced lifecycle costs, while also developing the operational concept to enhance the overall productivity of ANS provision (in terms of the services they provide their interdependencies) [1][3]. Applying the overall framework to a specific case study where any type of innovation could be injected, the EvoATM Open Demonstrator may provide valuable feedback to the strategic decision process. In fact, thanks to the analysis of system elements that influence at the most their related performances, the Open Demonstrator suggests what are the ATM system elements to be better tuned or modified, providing support at strategic system level.

REFERENCES

- [1] SESAR, , The Roadmap for Delivering High Performing Aviation for Europe, European ATM Master Plan, Executive View, pp. 56-58, Edition 2015
 - [2] G. Baxter, and I Sommerville, "Socio-technical systems: From design methods to systems engineering", *Interacting with Computers*, Vol. 23,1, pp. 4–17, January 2011.
 - [3] SESAR, SESAR 2020 Transition Performance Framework, SESAR Deliverable D108, June 2016.
- G. Gigante, D. Pascarella, M. Sánchez Cidoncha, M. A. Piera, G. Duca, N. Lettieri, L. M. Braga, J. L. Muñoz Gamarra, "ATM Change Management: an Evolutionary and Agent- Based Approach", *Proceedings of 2nd International Conference on Intelligent Traffic and Transportation (ICITT 2018)* Stokholm 22-24, September 2018.

Solutions for Increased General Aviation and Rotorcraft Airport Accessibility

The GRADE Project

Antonio Vitale, Edoardo Filippone, Leopoldo Verde
On Board Systems and ATM
Italian Aerospace Research Centre (CIRA)
Capua, Italy

Thomas Lueken
Institute of Flight Guidance
German Aerospace Center (DLR)
Braunschweig, Germany

Johan Debattista
Malta Air Traffic Services (MATS)
Luqa, Malta

Thomas Rausch
Institute of Flight Guidance
Technical University Braunschweig (TUBS)
Braunschweig, Germany

Alexander Zarbov
Programmes and Strategies Department
Bulgarian Air Traffic Services Authority (BULATSA)
Sofia, Bulgaria

Gabriella Duca
Human Factors & Ergonomics
Institute for Sustainable Society & Innovation (ISSNOVA)
Naples, Italy

Marco Cappella
Nextant Applications & Innovative Solutions (NAIS)
Rome, Italy

Giuseppe Del Core
Science and Technologies Department
University of Naples Parthenope (UNIPARTH)
Naples, Italy

Abstract—This short paper and the associated poster present the GRADE project, the aim of which is to demonstrate the capability of General Aviation and Rotorcraft to benefit from the concepts developed within the SESAR programme and already validated on Commercial Aviation aircraft. Specifically, the project focuses on SESAR solutions that enhance terminal operations by exploiting the global navigation satellite system.

Keywords—general aviation; rotorcraft; ATM; approach; global navigation satellite system.

I. INTRODUCTION

The SESAR programme is geared mostly towards improving Air Traffic Management (ATM) for the commercial air transport sector, operating Instrument Flight Rules (IFR) inside controlled airspace. However, the General Aviation (GA) and Rotorcraft (RC) communities should be able to benefit from the concepts developed in the SESAR programme as well, in order to facilitate their integration, in an efficient and non-discriminatory manner, into the airspace and at the airports where the SESAR concepts and technologies are implemented [1]. Within this framework, the GRADE project aims at demonstrating, through flight trials, the capability of GA and RC, equipped with non-certified on-board avionics and/or portable equipment, to exploit SESAR solutions based on the GNSS (global navigation satellite

system) technology, which will allow these aircraft to enhance terminal operations and increase their airport accessibility, whilst also ensuring safety [2]. The GRADE project, its objective and motivations, the demonstration approach and the expected outcomes of the project, are presented here.

II. THE GRADE PROJECT

The GRADE (Gnss solutions for increased general aviation and Rotorcraft Airport accessibility DEMonstration) project is a Very Large Scale Demonstration project, partially funded by the SESAR Joint Undertaking. The GRADE consortium is formed by CIRA (Coordinator), BULATSA, DLR, MATS, NAIS, TUBS, UNIPARTH (which is supported by the linked third party ISSNOVA). The project aims at demonstrating through live flight trials the operational feasibility and the acceptability, from both Air Traffic Control Officer's and Pilot's perspectives, of implementing some SESAR-1 Solutions on GA aircraft and RC equipped with non-certified on-board equipment. Fig. 1 and Fig. 2 present the operational concepts of the demonstration for GA and RC, respectively. In particular, SESAR Solutions #51, #55, #103 and #113 [3], are considered. Solutions #51 and #103 exploit Satellite Based Augmentation System (SBAS) GNSS technologies for Initial and Intermediate Approach Segments, and Final Approach Segment, respectively. Solution #55 enables

precision approach Category II/III procedures relying on Ground Based Augmentation System (GBAS) GNSS signals, which is considered of interest for the upper segment of the GA community. Solution #113 focuses on Optimized Low Level IFR routes for RC, based on GNSS signals. The satellite-based technology is an affordable alternative to the Instrumental Landing System (ILS) and contributes to augment accessibility and safety to all airports (including regional and small ones) for GA and RC not equipped with ILS airborne devices. Indeed, GNSS technologies improve aircraft navigation accuracy. They allow to reduce separation between arriving aircraft (improving airport throughput) without negatively affecting safety and human performance, especially in poor weather conditions. In addition, these advanced SESAR solutions may include curved legs [4], which increase flexibility in procedure design, allowing shorter approach paths that result in fuel savings, and may be used for avoiding environmentally sensitive areas (e.g. populated areas with noise restrictions). The GNSS technology also allows designing specific IFR routes for RC, enabling their operators to access into controlled airspace and fully integrating them into the future ATM system, by implementing the Point in Space (PinS) concept, which is a relevant element of SESAR Solution #113. Indeed, RC face significant weather and terrain-related challenges when performing specific flight operations (e.g. civil transport, medical emergencies, etc.). For these reasons, the RC operations are confined to fly only when they could meet strictly defined visibility conditions, limiting drastically their access to controlled airspaces and Terminal Maneuvering Areas. The PinS procedures have the potential to enable an increasing passenger throughput at medium and large airports, removing IFR RC from active runways and allowing an easier way to manage both traffic flows of fixed-wing aircraft and rotorcraft simultaneously in a non-interfering way.

The GRADE demonstration will involve professional air traffic controllers and pilots to operate the scenarios and will be conducted in the Italian airspace at Capua airport, using CIRA's FLARE experimental aircraft, and in the German airspace at Braunschweig airport, using TUBS's Cessna 172N and DLR's ACT/FHS research helicopter (Figure 3). Preparatory Real-Time Simulation (RTS) campaigns, with hardware and humans in the loop, will complement the flight trials, with the aim to achieve a preliminary assessment of measurable performance indices in realistic environments, to identify the most relevant scenario conditions to be tested in flight, as well as to assess any possible safety risks during the in-flight trials. Concerning GA, the project will focus on Very Light Aircraft (VLA) and CS-23E - Normal and Utility Category Airplane. The demonstration of same solutions on aircraft of different categories will highlight the scalability of the tested solutions, and their benefits therefore could be applicable to a wider range of general aviation aircraft. The project will also focus on technological aspects, by testing GNSS navigation algorithms able to guarantee the Required Navigation Performance (RNP), GBAS avionics equipment for GA with interfaces to standard instruments, and a portable non-certified Flight Display (Figure 4) to support pilot decisions and operations. Performance assessment, based on relevant Key

Performance Indicators in the area of Safety, Capacity, Environment and Human Performance, and lessons learnt will represent the main outcome of the project and could support regulation, standardization and certification activities, as well as the integration of GA and RC with commercial aviation. All the preparatory RTS have been completed in November 2018, collecting a large amount of data related to the addressed KPAs. Results of RTS analysis will be available by February 2019.

REFERENCES

- [1] SJU Annual Work Programme 2016, October 2016.
- [2] P. Neri, "Use of GNSS signals and their augmentations for Civil Aviation navigation during Approaches with Vertical Guidance and Precision Approaches", PhD Thesis, University of Toulouse, November 2012.
- [3] SESAR Solutions Catalogue - First Edition, 2016.
- [4] R. Geister, T. Dautermann, V. Mollwitz, C. Hanses, and H. Becker, "3D-Precision Curved Approaches: A Cockpit View on ATM", Tenth USA/Europe Air Traffic Management Research and Development Seminar (ATM2013), June 2013.

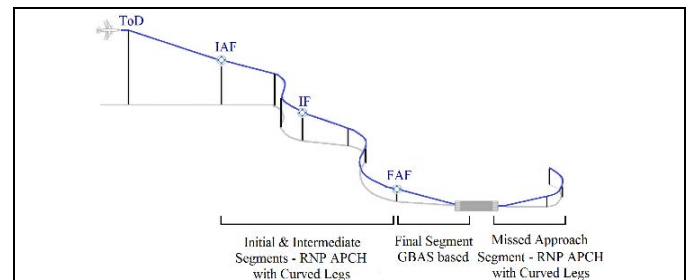


Figure 1 Operational context for GA demonstration

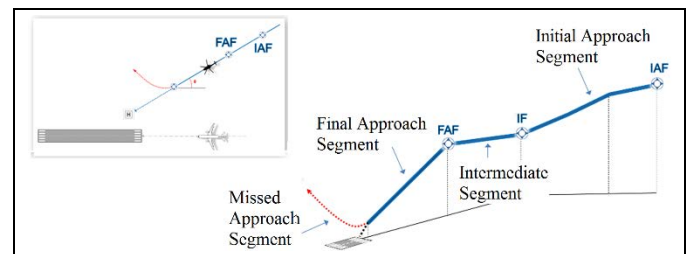


Figure 2 Operational context for RC demonstration



Figure 3 Experimental aircraft used for the GRADE demonstration

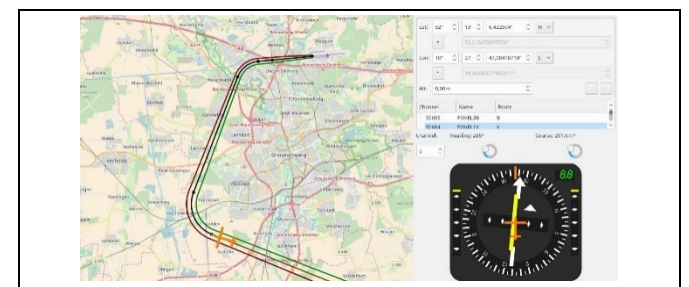


Figure 4 Example of GRADE application available on portable display

An Approach to Define Adverse Weather Zones Based on the Flight Management Performed by Pilots in Convective Weather Events

Ulrike Gelhardt, Jürgen Lang
MeteoSolutions GmbH
Darmstadt, Germany
ulrike.gelhardt@meteosolutions.de

Stefan Schwanke
Planung und Simulation (OP)
DFS Deutsche Flugsicherung GmbH
Langen, Germany
stefan.schwanke@dfs.de

Abstract— The project which was conducted within the SESAR2020 PJ10 framework aims to define ATM-tailored two-dimensional convective areas (then known as 'adverse Wx zones') that pose a safety risk to air traffic because of prevailing weather conditions, such as lightning, gusts or hail, and which are therefore to be avoided by aircraft. MeteoSolutions GmbH, Deutscher Wetterdienst (German Meteorological Service) and Deutsche Flugsicherung GmbH (German air traffic control) partnered in this one year study.

Convection, weather radar reflectivity, adverse Wx zones, flight trajectories, pilot deviation behaviour in thunderstorm situations, real-time simulation, air traffic controller

I. INTRODUCTION

Using conventional ground-based weather radar data, a reflectivity threshold of 37 dBZ has frequently been used in aviation as main criterion for describing such dangerous convective weather events. The dimensions of the area determined by this threshold define a convective area. The value was determined empirically in the 1980's based on a six-class reflectivity product. This criterion, which is since then and still often used in aviation to define dangerous convective areas, was to be verified and, if necessary, redefined. The actual lateral navigation behaviour as objectively documented in flight trajectories and subjectively stated in interviews of pilots during convective events was to be considered.

II. DATA AND METHOD

For the study two meteorological data bases were used to define convective areas. One was the new so-called NowCastMIX-Aviation (NCM-A) warning product from the Deutscher Wetterdienst (DWD, German Meteorological Service), which was developed especially for aeronautical meteorology. The input data for the product are radar products, observations, lightning data and numerical model predictions (https://www.dwd.de/EN/research/weatherforecasting/met_applications/nowcasting/nowcast_mix_en_node.html). The warning product differentiates between five severity categories

ranging from heavy rain (warning level (WL) 0) to light (WL1), moderate (WL2), heavy (WL3) and extreme thunderstorm activity (WL4). For this project, the warning product generated at the analysis times was needed. The other data base was the radar reflectivities from DWD weather radars, which were used to reveal a potential direct connection between radar reflectivities and air navigation behaviour in particular. Both products are available in polar stereographic projection on a 900 x 900 grid over Germany with equidistant grid-spacing of 1 km. They are updated every five minutes.

To incorporate lateral navigation behaviour into the evaluation, information on the routes planned and flown was needed. Anonymized flight trajectories with a temporal resolution of 4 seconds were provided by DFS. In addition to time dependent parameters like UTM coordinates, altitude, ground speed and flight phase, additional information like aircraft and engine type and wake turbulence category were available. To back up and enhance this objective information, several interviews with passenger and cargo airline pilots have been conducted regarding their behaviour and influencing data and parameters when diverting to a convective cell.

As flight trajectory data and meteorological products were available in different temporal and spatial resolutions, warning level information and radar reflectivity values along the route were assigned spatially and temporally. The study area was limited to the lower airspace controlled from Bremen ACC (up to FL 245). For June 2017, around 20 periods of weather situations with convection were determined according to pre-defined criteria by DWD and the corresponding data for these periods were prepared, merged and statistically evaluated.

III. RESULTS AND DISCUSSION

The evaluation of the data merging of flight trajectories with the respective spatial and temporal assigned warning levels shows a significant decrease in the number of flights through convective areas with the increasing intensity of the warning level as expected. Taking into account the different

frequency of occurrence of the individual warning levels, it can be seen that the warning levels 0 (characterised by heavy rainfall) and 1 (areas with lightning activity) are flown through very frequently, especially when their occurrence is singular, whereas this is much less frequently the case for the higher warning levels. It is noticeable that especially in areas with warning level 0 in the radar product, the spatially assigned reflectivity values are below 37 dBZ. In addition, in areas with convection only short distances (less than 15 NM) are usually flown and a strong behaviour dependence on the flight altitude i.e. flight phase is noticeable.

Based on this evaluation, for the definition of adverse Wx zones it is proposed that either only the grid points of warning level 0 are assigned a warning level where the radar product exceeds a pre-defined threshold value or that warning level 0 is completely excluded. A re-examination of warning level 1 must also be considered. In a similar way to warning level 0, it is proposed to only define grid points with warning level 1 as "adverse" if the assigned radar value is also greater than the specified threshold value.

The higher warning levels (2-4) can be adopted unchanged in principle. The visual examination of individual routes showed that concrete avoiding action was often visible in the

trajectories. In particular, warning levels 3 and 4 may be associated with the occurrence of hail. This is a clear criterion for flying around these areas. However, since air traffic controllers and pilots only want 2-3 gradations of hazard potential (similar to the on-board radar of the pilots), it would make sense to combine warning levels 3 and 4 into one zone.

IV. OUTLOOK

In iterative follow-up activities the next months, it is planned to validate this approach of adverse Wx zones in real-time simulations with air traffic controllers' judgement and after fine-tuning and testing to include these convective areas into controller assistance applications like conflict detection and reasonable trajectory prediction (what if / what else probing).

ACKNOWLEDGMENT

This project has received funding from the SESAR Joint Undertaking under grant agreement No 734143 under European Union's Horizon 2020 research and innovation program.

We thank DWD for providing meteorological data.

RADIAN Project

Roland Guraly, Andrej Kocsis, Seyed Reza Mirhossein

Slot Consulting
Budapest, Hungary
info@slotconsulting.hu

Abstract – As the aviation sector is a fast growing sector of Europe's economy and is associated with a wide range of economic and societal benefits – acting as a catalyst of technology transfer to many fields of mainly industrial application and vice versa taking up technologies from other sectors – it is expected that those European regions that will strengthen their Research, Development and Innovation (RDI) cooperation in aviation activities will significantly benefit both in the medium and in long term. RADIAN tends to identify the main reasons that block efficient cross-European aeronautics and air transportation (AAT) research cooperation and act as facilitator in future collaboration. Especially those regions should be considered where the actual cooperation level lacks the possibilities, capacities and skills, including recently associated countries.

Keywords-component; *Aviation research, collaboration platform, innovation, UAS, matchmaking, networking.*

I. INTRODUCTION

RADIAN (Facilitating Collaboration in Research and Development to Foster Further Innovation in European Aeronautics, www.h2020-radian.eu) is a Horizon 2020 EU cofounded project (started 1 October 2016 and will finish at 31 September 2019.)

RADIAN is a multi-step project which intends to overcome the misbalance in the involvement in aviation research across Europe by identification of barriers for international collaboration in aviation research at EU level, and by subsequent development and verification of solutions and measures on level of the European regions.

The goal is that researchers at both universities and research organisations cooperate in a fully integrated network irrespective of its location, size and financial possibilities with stronger involvement of commercial companies and special emphasis on emerging new developments (such as the Unmanned Aircraft Systems' (UAS) market) by building new supply chains.

II. METHOD

RADIAN has to consider all the regions of the European Union and the issues at the associated states of H2020 of the geographic Europe; however, this top-level view shall

therefore be focused on a manageable number of regions which have the potential to best profit from measures that can be initiated and supported by a project like RADIAN.

The field of regions can therefore be limited to "regions of interest" (ROI): regions, which fulfil the basic requirements for RADIAN:

- to have low involvement in aviation research and/or low participation in the EU Framework Programmes,
- to have the ambition and/or to possess the potential to significantly improve that status in the short- to medium-term time frame.

RADIAN tries to facilitate networking in many angles:

- Among leading member states in aviation research and states which are yet less integrated of the geographic Europe
- Via direct channels (facilitation meetings at selected regions, workshops) and indirect channels (dissemination of best practices, ARCPORT platform, etc.)
- both in aeronautics and air transport research

The most relevant activity for SESAR activities is to facilitate information sharing and network building in the field of Unmanned Aircraft Systems' (UAS) and drone related developments. The project supports building new research and supply chains by facilitating networking.

The RADIAN project considers following areas of interest related to UAS:

- Ground – air communication
- Technical solutions
- ATM related issues
- Regulatory aspects
- Possible areas of implementation
- Application possibilities and use cases

RADIAN established links with the CORUS project of SESAR. CORUS stands for Concept of Operation for European UTM Systems. As Gathering experts from aviation (manned and drone), research and academia, is in the focus of

both projects, they can share information with each other and do presentations at the events of each other.

In the frame of this process RADIANT organizes three regional workshops on drone and UAS RDI in the following states: Ukraine, Poland and Hungary (in the respective selected regions according to the RADIANT workplan). Moreover the project tries to involve researchers from other states from Europe (e.g. France, Italy, the Netherlands, etc.) to engage into networking dialogues in terms of developments and legal and administrative framework as the project finds that there are a lot of overlapping activities in Europe.

To ensure results the RADIANT project partners collect information on organizations from the target regions. The collected information relates to their capabilities, areas of interests existing and desired project partners and affiliations with major industry players.

III. RESULTS

The collected information will be used to set up networking events and to support matchmaking process. The events could be local with the invitation of the major European players or

events like AeroDays 2019 in Romania next year to which the contacted organizations will be invited.

To keep up the work of the project after its end an Internet based platform being developed named ARCPORT. The platform uses the knowledge accumulated and methodology developed during the life of the RADIANT project and will provide a virtual space for collaboration of researchers that have intention to participate in aviation related calls.

The platform combines various information on the researchers and on upcoming calls as well. The users profile will reflect the users capabilities and interests to enable networking and in the same time the call related information will be selected and presented to user according to that profile. The platform will also support communication between the users in various forms starting with newsletters all the way to the personalized chatrooms for initial proposal preparation.

REFERENCES

- [1] <http://www.h2020-radian.eu>
- [2] <http://uavhub.nau.ua/>

Vertical Flight Trajectory Efficiency

A quantitative study on the effects and causes of climb restrictions for flights departing Amsterdam Airport Schiphol

Marc Eijkens

Strategy and Performance
Air Traffic Control the Netherlands (LVNL)
Schiphol, the Netherlands

Preferably a flight departs such that it can fly an uninterrupted climb to the requested cruise altitude, as this is considered most efficient. Due to multiple factors departing flights are not always able to continuously climb to the requested cruise altitude, resulting in increased fuel consumption creating additional CO₂ emissions. The majority of the level segments occur in the Terminal Maneuvering Area and near the boundaries of the Dutch airspace where flights are transferred to air traffic control in the United Kingdom. The conclusions are that the current hand-over conditions with the neighboring air navigation service providers negatively impact the vertical efficiency of departures from Schiphol Airport, while the level segments in the Terminal Maneuvering Area create the majority of additional fuel consumption due to crossing arrival and departure routes. These insights are to be used when redesigning the Dutch airspace in the near future, to determine optimal flight routes.

Keywords: Continuous Climb Operations; Level segments; Trajectory efficiency; Fuel consumption.

I. INTRODUCTION

Air traffic controllers strive to accommodate flights with climb instructions to enable a continuous climb departure while ensuring safety. A continuous climb departure is a vertical flight profile where an aircraft is able to reach the initial cruise altitude without any interruptions. However, accommodating a continuous climb is not always achievable, resulting in level segments at sub-optimal altitudes. These level segments increase fuel consumption of aircraft due to flying extended periods at these sub-optimal altitudes. This additional fuel consumption creates increased amounts of greenhouse gasses and other pollutants. The objective of this research is to determine and quantify the causes of interrupted climb profile for flights departing Schiphol and how this affects aircraft operators in terms of additional fuel consumption and CO₂ emissions.

II. METHODOLOGY

This research follows a similar methodology as used by the Performance Review Unit (PRU) and Peeters to detect level segments [1],[2]. The primary difference in this research is the trajectory data source and the addition of fuel consumption calculations. Detailed Secondary Surveillance Radar (SSR) data is used to provide high resolution position data at four

second intervals. Over 40,000 flights departing Amsterdam Airport Schiphol were analyzed in the months of February and July of 2017 to determine the effects of seasonality.

A. Detecting level segments

A level segment is defined as a section where the average rate of climb is less than the threshold value of 300 feet per minute (1). A minimum interval length of twenty seconds is used to dampen sudden fluctuations in the SSR data. Only the climb phase located within the area of responsibility of Dutch air traffic controllers is analyzed. Fig. 1 illustrates the detection of a level segment during climb.

$$\frac{\Delta Y}{\Delta X} \leq 300 \text{ ft/min} \quad (1)$$

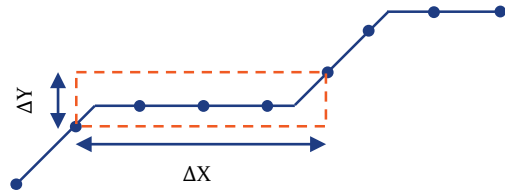


Figure 1. Level segment detection in climb phase

B. Determining additional fuel consumption

The distance of a level segment at a sub-optimal altitude could have been travelled at the optimal cruise altitude. Since fuel flow is based on time, the equivalent time to travel the distance at cruise altitude is calculated. EUROCONTROL Base of Aircraft Data (BADA) [3] is used to estimate the fuel burn for both the actual level segment and the equivalent segment at the optimal cruise altitude. The difference in fuel burn between the level segment and equivalent segment is considered the inefficiency caused by the level segment

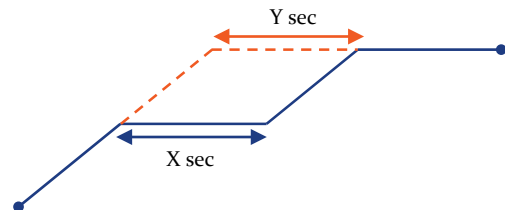


Figure 2. Level segment X versus equivalent segment Y at cruise altitude

III. RESULTS

An overview of vertical trajectory efficiency is shown in Table 1. The influence of location, altitude, and operational variables (standard instrument departure route, departure runway, coordination exit point, and air craft type) are analyzed in order to determine how these factors affect the rate of occurrence, distance, and additional fuel consumption of level segments.

A. Location and altitude

Fig. 3 depicts the concentrations of level segment, three distinct regions and altitudes of the Amsterdam FIR :

1. South-West Schiphol TMA at FL60
2. South-West border with London AC at FL240
3. North-West border with London AC at FL240

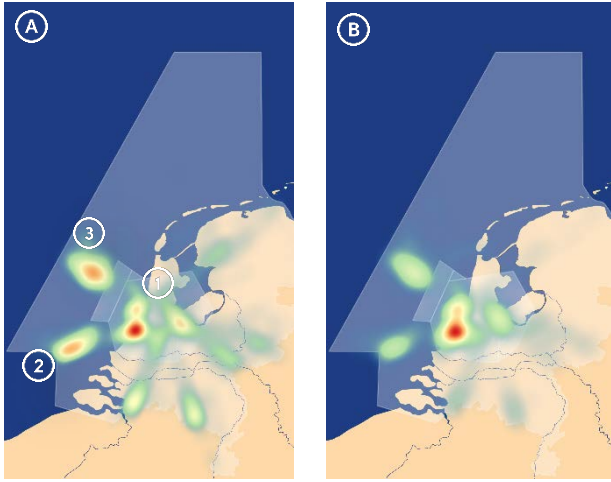


Figure 3. Concentration of level segments (A) and concentration of additional fuel consumption (B)

B. Additional fuel consumption

Fig. 4 depicts that the majority (37.5%) of all additional fuel consumption is due to level segments located at FL60, while only 18% of the total level segment distance is at this altitude. The secondary source of additional fuel consumption is at FL240, specifically for segments near the border with London AC.

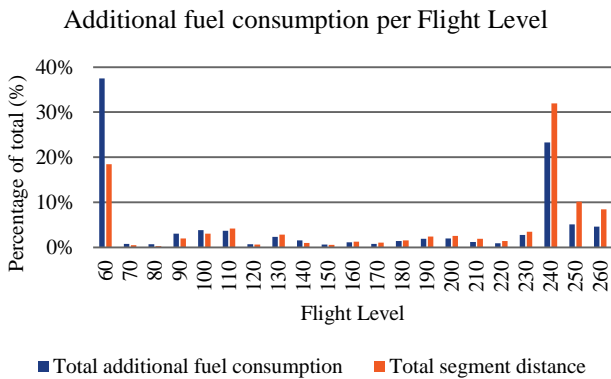


Figure 4. Distribution of level segments and additional fuel consumption per Flight Level

Table 1 Vertical Trajectory Efficiency in February and July 2017

Vertical Trajectory Efficiency 2017		
	February	July
Number of flights	16,910	23,505
% interrupted flights	9.9%	7.8%
Additional fuel consumption (kg)	20,027	21,138
Total time spent level (min)	1,665	1,882
Average time spent level per affected flight (sec)	59.7	61.6
Number of flights	16,910	23,505

IV. CONCLUSIONS

Interrupted climb: Over 90% of all flights are able to fly a continuous climb departure while under control of Dutch ATC. The PRU determined that 80% of all flights operate continuous climb departures out of Amsterdam [2].

Airspace design and ATC procedures: The majority of the level segment distance occurs at the hand-over altitude of FL240 near the border with the UK. Intersecting departure and arrival routes require vertical separation and produce most of the low altitude level segments in the Schiphol TMA.

Environmental impact: A total of 250,000 kg fuel was consumed on top of the regular fuel burn, primarily due to level segments in the Schiphol TMA. Each affected flight consumed on average 12 kg of additional fuel. This is similar to the 15kg of additional fuel per impacted flight according to PRU research², which included the entire climb phase. The additional fuel consumption results in nearly 800,000 kg of CO₂ emissions per year.

V. RECOMMENDATIONS

Enhance hand-over agreements with neighbouring ANSPs to accommodate continuous climb departures.

Develop solutions to reduce the effect of crossing departure and arrival routes in the TMA when redesigning the airspace.

Analyse the vertical trajectory efficiency of arrivals and determine their influence on flights departing Schiphol.

ACKNOWLEDGMENT

This work was supported by Air Traffic Control the Netherlands (LVNL), KLM, Amsterdam Airport Schiphol (AAS), and the Amsterdam University of Applied Sciences (AUAS). The author gratefully acknowledges the helpful discussions with Alina Zelenevska (LVNL), Evert Westerveld (LVNL), Coen Vlasblom (KLM), Boudewijn Lievegoed (AAS), Ferdinand Dijkstra (FerWay), and Frenchez Pietersz (AUAS).

REFERENCES

- [1] S. Peeters and G. Guastalla, "Analysis of en-route vertical flight efficiency," EUROCONTROL, 2017.
- [2] EUROCONTROL. "Vertical Flight Efficiency," Performance Review Unit, 2008.
- [3] EUROCONTROL. "User manual for the Base of Aircraft Data (BADA) Revision 3.14," June 2017.

Contemporary Wildlife Risk Challenges and Habitat Management in the Vicinity of Airports

Aleksandra Nešić

Faculty for Transport and Traffic Engineering
University of Belgrade
Belgrade, Serbia
aleksandra.nesic@air-mark.com

Olja Čokorilo

Faculty for Transport and Traffic Engineering
University of Belgrade
Belgrade, Serbia
o.cokorilo@sf.bg.ac.rs

Abstract—New challenges in aviation keep emerging, those require innovative solutions and new methods. Wildlife hazard as one of those requires creative strategies, diligent performance and detail-oriented approach. Increasing air traffic volume and population of some animal species together with undesirable combination of airport's area characteristics contribute to increased wildlife strike risk. Special pressure is on airports to provide safe environment, but are the airports the only responsible and the most important, are the airports capable to maintain safe conditions independently?

Keywords—component; wildlife risk; habitat management; airport

I. INTRODUCTION

Wildlife strikes mainly occur at low flight altitudes, somewhere in the airports' vicinity. Existence of some wildlife attractants in the airport's area additionally increases animals' presence. The research identifies wildlife attractants that may significantly impact wildlife risk, with accent on habitat management and risk mitigation challenges in the airport's environment.

II. RESEARCH CONTENT

A. Area of concern

Majority of wildlife strikes occur during flight phases that involve aircrafts low altitude, such as take-off and landing. Therefore, the wildlife risk assessment and mitigation process should comprehend the airport's environment. Airports should conduct an inventory of wildlife attracting sites within the ICAO defined 13 km circle, paying attention to sites close to the airfield and the approach and departure corridors. Which makes area of concern significantly wider than airport property.

B. Wildlife strike reporting

Proper reporting of wildlife occurrences (observed strike, cases when strike evidence is found on the aircraft or animal remains are located close to the runway) is crucial for the accurate risk assessment. Correct, detailed and timely reporting of wildlife strikes will determine quality of data which will be used for the risk evaluation and in the process of making decision which prevention measures will be applied [1].

C. Methodology

Any element that provides food, water or shelter in the airport area represents hazardous wildlife attractant. Those attractants may be temporary formations, natural characteristics, human activities, etc. The research identifies highly risky elements that should be considered in the wildlife risk management process. Identified highly hazardous attractants are categorized and individually analyzed.

D. Habitat management

If hazardous wildlife is detected, corrective actions should be immediately implemented [2]. Efficient habitat management may require measures like landfill relocation, forest and shrubs removal, water drainage, airport fencing, using disperse devices, tracking radars, pyrotechnic and chemical aids, seeding programme review and many others. These measures may be applied individually or combined.

E. External stakeholders engagement

Although airport's role is vital, resources and power are limited. In many cases local authority support and raising public awareness are needed. Local community engagement may ensure long term benefit. Beside highlighting what are the airports' limitations, research elaborates why independent airport activities are insufficient for the proper wildlife strike risk mitigation.

III. CONCLUSIONS

Despite being very important component, habitat management won't be able to eliminate wildlife strike risk. Certain level of this risk will always be present. Every party in aviation in its working domain may contribute to the process of wildlife risk mitigation. Complexity of this process may require external participants, outside the aviation industry.

REFERENCES

- [1] A. Nešić, O. Čokorilo and V. Jović, "Bird strike risk assessment at the Milwaukee's General Mitchell International Airport," In Proceedings of the International Conference on Traffic and Transport Engineering (ICTTE 2018), 2018, pp. 49-58.
- [2] FAA, "Hazardous Wildlife Attractants on or Near Airports," AC 150/5200-33B, US Department of Transportation, Federal Aviation Administration, 2007, p.16.

pyBADA: Easy BADA Integration in Python for Rapid Prototyping

Ramon Dalmau, Marc Melgosa and Xavier Prats
Department of Physics - Aerospace division
Technical University of Catalonia
Castelldefels, Spain 08860

Abstract—The base of aircraft data (BADA) model provides accurate modelling of aircraft performances over the complete flight envelope for flight simulation and prediction applications. BADA is based on a generic total energy model, which performance functions (e.g., drag, maximum and minimum thrust, fuel flow) are particularised for each aircraft type with coefficients included in the BADA databases. BADA has a high reputation within the academic and research world, thus it is widely used for air traffic management research applications. This poster presents the architecture and capabilities of pyBada, a Python-based software designed for the easy integration of the BADA model in trajectory simulation, prediction and optimisation applications.

Keywords—BADA, Python, aircraft performance, optimisation

I. INTRODUCTION

The current air traffic management (ATM) is facing issues regarding environmental impact, cost-efficiency, safety and capacity. Aiming to address these challenges, the US and Europe are modernising their ATM systems through the NextGen and SESAR programmes, respectively. In this context, many modelling and simulation tools are developed by the ATM community to assess the future ATM systems and concepts of operation. Aircraft trajectory simulation, prediction and optimisation are key functions of these tools. In order to obtain realistic results, these functions require an aircraft performance model (APM) to accurately represent aircraft behaviour.

The two main approaches to aircraft performance modelling for prediction, simulation and optimisation of aircraft trajectories are kinematic and kinetic. The former describes the movement (i.e., displacement, velocity) of the aircraft without taking into account the underlying physics; while the later approach models the forces acting on the aircraft, which cause its motion. The Base of Aircraft Data (BADA) is an APM based on the kinetic approach developed and maintained by Eurocontrol, with the active cooperation of aircraft manufacturers and operating airlines. BADA was designed for trajectory prediction and simulation for purposes of air traffic management (ATM) research and operations [1], [2], and has high reputation within the academic and research world.

The BADA APM has been used in many ATM research applications, ranging from agent-based air traffic simulations [3]; fast-and real-time modelling and simulation tools [4]; environmental assessment tools [5]; assessment of new concepts of operations for the future ATM paradigm [6]; trajectory optimisation algorithms [7]; and trajectory prediction tools [8].

However, parsing the BADA datasets, coding the model specification and computing the derivatives of the performance functions (e.g., for trajectory optimisation purposes) could be a tedious and time consuming task which takes resources that could be devoted to the actual goal for which BADA is used.

At present, there exist a compiled library produced in C/C++ and provided by Eurocontrol that saves the hassle of coding the BADA model specification, thus minimising the chances of coding errors and reducing the implementation time. However, the compiled code produced in C/C++ most often runs on top of the hardware architecture upon which it is written. While this typically makes the code run faster, it could have the undesirable effect of making a compiled program machine and processor dependent. Furthermore, despite allowing the user to efficiently parse the BADA datasets and evaluate the BADA performance functions (e.g., fuel flow) at various flight conditions, the existing library does not provide function derivative information, which is of utmost importance for state-of-the-art, gradient-based trajectory optimisation algorithms.

The poster will present pyBada, a multi-platform library designed for a rapid, easy and transparent integration in Python of the BADA APM for ATM research purposes. The applications of pyBada include aircraft performance modelling, trajectory prediction and optimisation, and visualisation.

II. BACKGROUND

The pyBADA library allows for easy parsing of the BADA datasets and evaluation of the BADA performance functions and their derivatives at various flight conditions. The derivatives of the BADA performance functions are computed by using the automatic differentiation algorithms provided by the CasADi framework. Section II-A presents the BADA model; while Section II-B describes the CasADi framework.

A. Base of aircraft data

The base of aircraft data (BADA) aircraft performance model is based on the following total energy model (TEM):

$$\begin{aligned}(T - D)v &= mgh + mv\dot{v} \\ \dot{m} &= -f\end{aligned}\tag{1}$$

where T is the thrust of the engines; D the aerodynamic drag; m the mass of the aircraft; v the true airspeed (TAS); g the gravity acceleration; h the altitude and f the fuel flow.

In BADA, the thrust, drag and fuel flow functions of Eq. (1) are polynomial expressions which depend on a set of coefficients. Each aircraft type has a corresponding set of coefficients, which are specified in the BADA datasets. These datasets are ASCII (American Standard Code for Information Interchange) or XML (eXtensible Markup Language) formatted files, depending on the particular BADA family.

There exist three BADA families: BADA v3, designed to model aircraft behaviour over the normal operations part of the flight envelope; BADA v4, aimed at providing modelling capabilities for the complete aircraft flight envelope; and BADA H, which was recently released for modelling of helicopters. Regardless of the BADA family, parsing the datasets could be a tedious task requiring some programming skills; implementing the model specification could lead to potential coding errors due to the complexity of the performance functions; and computing the derivatives of these functions could be a cumbersome exercise requiring mathematical background.

B. CasADi

Despite CasADi started out as a tool for algorithmic differentiation (AD) the main focus of the framework rapidly shifted towards optimisation [9]. At present, CasADi provides a set of tools that drastically decreases the effort needed to implement algorithms for optimisation, yet without sacrificing efficiency.

The core of CasADi consists of a symbolic framework that allows to construct symbolic expressions and use these to define automatically differentiable functions. Once the expressions have been created, they can be used to obtain new expressions for derivatives or be efficiently evaluated.

III. PYBADA

According to the stack overflow trends, Python has been growing rapidly in the last few years. In fact, the latest report from Forbes shows that Python showed a 456% growth in 2018. Python was also placed at 3th place in the 2018 redmonk programming rankings, which order programming languages by the number of pull requests for code repositories on GitHub and tags on questions of stack overflow. Predictions show that Python continues to climb the ranks of the most popular programming languages. This is not surprising, since Python has many positives features: Firstly, Python code is relatively easy to read and understand; secondly, it supports multiple programming paradigms; thirdly, it has a large list of libraries.

pyBADA is a Python library build on top of CasADi, which has been developed by researches of the Technical University of Catalonia (UPC) for the easy implementation of aircraft performance modelling and trajectory prediction and optimisation algorithms with BADA. Besides allowing the user to parse the BADA datasets and evaluate the BADA performance functions with minimum programming effort, pyBADA can be also used to generate symbolic expressions of these functions to easily obtain their derivatives using AD thanks to the CasADi functionalities. This allows easy implementation of many trajectory optimisation and prediction algorithms, and sensitivity analysis requiring derivative information.

Furthermore, pyBada is multi-platform (i.e., it can be used in the most popular operative systems) and is very easy to install via pip, one of the most famous and widely used package management system to install Python packages.

pyBada is composed by several modules:

- **Atmosphere module:** This module implements standard atmosphere and simplified wind models; it also provides conversions tools of aircraft speeds, e.g., Mach to TAS.
- **Performance module:** This module parses the BADA datasets of the three BADA families; evaluates the performance functions of BADA at given flight conditions; and provides efficient derivatives of these functions.
- **Optimisation module:** This module calculates optimal speeds and altitudes for given flight conditions (punctual optimisation); and generates optimal trajectories in the vertical domain (integral optimisation).
- **Trajectory prediction module:** This module provides tools for predicting aircraft trajectories given the initial conditions, the BADA datasets, a sequence of flight intents and weather conditions.
- **Visualisation module:** This module provides tools for visualisation of aircraft trajectories, aircraft envelope and performance. It allows to visualise complex expressions such as the maximum rate of climb as a function of the altitude and speed.

REFERENCES

- [1] E. Gallo, F. A. Navarro, A. Nuic, and M. Iagaru, "Advanced aircraft performance modeling for atm: Bada 4.0 results," in *IEEE/AIAA 25th Digital Avionics Systems Conference (DASC)*, Portland, OR, Oct 2006.
- [2] D. Poles, A. Nuic, and V. Mouillet, "Advanced aircraft performance modeling for atm: Analysis of bada model capabilities," in *IEEE/AIAA 29th Digital Avionics Systems Conference (DASC)*, Salt Lake City, Utah, Oct 2010.
- [3] P. Volf, D. Sislák, and M. Pechoucek, "Large-scale high-fidelity agent-based simulation in air traffic domain," *Cybernetics and Systems*, vol. 42, pp. 502–525, 2011.
- [4] "Total Airspace and Airport Modeler (TAAM) factsheet," Jeppessen, 2018.
- [5] L. Cavadini and I. de Lpinay, "Assessing trends in aviation noise and emissions in Europe using advanced modelling capabilities IMPACT & AAT," in *2nd ECATS Conference*, Athens, Greece, November 2016.
- [6] R. Dalmau and X. Prats, "Fuel and time savings by flying continuous cruise climbs. Estimating the benefit pools for maximum range operations," *Transportation Research Part D: Transport and Environment*, vol. 35, pp. 62–71, 2015.
- [7] M. Soler, A. Olivares, and E. Staffetti, "Framework for aircraft trajectory planning toward an efficient air traffic management," *Journal of Aircraft*, vol. 49, no. 1, pp. 341–348, January 2012.
- [8] E. Gallo, J. Lopez-Leones, M. A. Vilaplana, F. A. Navarro, and A. Nuic, "Trajectory computation infrastructure based on bada aircraft performance model," in *IEEE/AIAA 26th Digital Avionics Systems Conference (DASC)*, Dallas, TX, Oct 2007.
- [9] J. A. E. Andersson, J. Gillis, G. Horn, J. B. Rawlings, and M. Diehl, "CasADi – A software framework for nonlinear optimization and optimal control," *Mathematical Programming Computation*, In Press, 2018.

Data-driven Insight in Aircraft Taxi Time

Seyed Reza Mirhossein, Andrej Kocsis, Roland Guraly

Slot Consulting
Budapest, Hungary
info@slotconsulting.hu

Abstract – Prediction in SESAR exploratory research might be mostly within aerial data, however, the indirect impacts of ground activities should be considered as well to optimize the airport operation. Embedded knowledge within the generated data has become the focal point for strategist and industry management to assess all historical events in order to extract valuable information for future decision making. The most crucial and complicated part of flight operation is dedicated to airport operation where all involved partners are running to meet the pre-scheduled time slots and lead the competitive market. Leverage data-driven solutions in turnaround process and specifically, aircraft taxi time is just an example to promote utilization of massive generated data within airport in order to optimize operational efficiency.

Keywords—component; Data-driven, machine learning, A-CDM, prediction, turn-around, taxi time.

I. INTRODUCTION

Aircraft activities on the ground could be divided in two major parts namely as; all activities between in-block and off-block which are assigned to contracted ground handling partner, while the second part is the essential process of aircraft taxiing schedules. To be more precise, considering all collaborative responsibilities, the ultimate responsible for first phase (between block times) are appointed to ground handling service providers, on the other hand, the second phase (Taxiing) might be affected by many factors despite is not associated to a specific stakeholder as direct responsible or supervisor. Accordingly, seeking for analytics models in taxi time prediction would lead to a higher turnaround performance by providing frequent predictions throughout learning from historical data.

The fundamental phases of aircraft turnaround are ground handling sequential activities and taxiing. Aircraft taxi time is defined as the time that an aircraft spends taxiing between its parking stand and the runway or vice versa. Moreover, The ambiguity of the duration of aircraft taxi time beside the involvement of various unknown factors have resulted in importance of better understanding of its behaviours and identify a series of analysis and prediction methods both for departure and arrival flights.

II. METHOD

Machine learning algorithms and data mining processes are known as pioneer means to reach a better performance in hectic airports, while the quality of prediction highly depends on many other factors such as data attributes, data volume, deployed technologies and usability in stakeholder environment. So far, This poster is intended to represent simple, straightforward and feasible data driven solution to serve ATM and other stakeholders in two main areas:

- Provide descriptive analytic information about different factors in aircraft taxi time prediction and investigate further trends within operational data
- Introduce the best performing prediction algorithm and demonstrate validation methodology to be utilized in production

Exploratory data analysis shapes the ground of the study and provides insight for not only target variable but also reveals the general trend and particular data behaviour. The gained knowledge through data exploration would initially help to clean and prepare data to be deployed in desirable algorithms, secondly shows the statistical characteristics of the data points and correlations in visual methods.

III. RESULTS

Significant emission reduction is another benefit of this analytic approach in production. Initially, a better knowledge about predicted taxi time would directly decrease number of aircraft queuing at the taxi ways with considerable CO2 emission reduction, also it cuts additional fuel cost to the airlines as well. Furthermore, provided insight of taxi way and runway occupation will facilitate the implementation of SESAR solution as E-AMAN¹, allows sequencing aircrafts in flight and sort them for landing (by setting new cruise speed or altitude) much earlier than airport airspace in order to optimize fuel efficiency and eliminate delays due to congested airport.

¹ Extended Arrival Management

Eventually, Model validation helps to choose the best model among all algorithms and introduces the benefits, constraints and basic requirements to implement the prediction models in production. The analysis and interpretation of the model features also provides a brilliant information out of data with respect to algorithm specifications. Moreover, having the best deployed model, a high-level evaluation of the expected outcomes of the solution has been calculated. This assessment is originated from evaluation of the A-CDM impact at local/airport level as well as at network level in 17 fully implemented CDM airports considering the current state of the proposed model accuracy. Series of KPIs present the expected benefits of optimized taxi time prediction at a congested airport like JFK.

IV. REFERENCES

- [1] Hadley Wickham, Garrett Golemund "R for Data Science," 1st edition, Chap 12, 25, Dec 2016.
- [2] IATA, ACI & Eurocontrol "Airport CDM implementation", Chap 3, Mar 2012
- [3] Andy Kirk "Data Visualization, a handbook for data driven design", part 6 & 7, 2016, Reference book
- [4] Allen B.Downey "Think Stats" Ch 1 & 2 & 7, Oct 2014
- [5] SESAR Budapest 2.0 project "The international collaboration demonstrating ATM developments with live traffic has been completed"
- [6] SESAR BEST project "Achieving the benefits of SWIM by making smart use of semantic technologies"
- [7] H2020 AirportIQ project "aims to improve the quality of the information that is used in turnaround"
- [8] David Bowen "Trajectory Based Operations", SESAR joint undertaking
- [9] SESAR QM-7 "Update of 5.6.4 OSED_Step 1" from project "Integrated sequence building/optimization of queues", 00.01.01

Aviation Collaborative Research

Frenchez Pietersz

Aviation Academy & Centre of Excellence

Amsterdam University of Applied Sciences & Knowledge Development Centre Schiphol

Amsterdam, the Netherlands

f.pietersz@hva.nl & frenchez.pietersz@lvnl.nl

Abstract—Collaborative research supports the aviation industry because knowledge and insights gained are linked to the sector goals and provide tools to tackle the challenges. The collaboration between Air Traffic Control the Netherlands (LVNL), KLM, Schiphol Airport and Ministry of Infrastructure and Water Management (I&W), in the Centre of Excellence generates results that are only attained through the objective and active involvement of aviation organizations. A joint undertaking between industry and universities, allows BSc and MSc graduates to research detailed and sensitive company information nonetheless still create results available to the public domain and the whole aviation sector. The results of the researches are among providing new insights in gate usage, vertical flight efficiency and on-time performance developments at Schiphol Airport. In addition, the results are already used in discussion with the stakeholders to improve current and future operations. Collaboration on this level is highly recommended for any country/ hub airport where congestion challenges exist or to proactively prevent these from occurring.

Keywords; A-CDM; Amsterdam Schiphol Airport; Centre of Excellence; Collaboration; I&W; KLM; Knowledge Development Centre; LVNL; OTP; Universities; Vertical Flight Efficiency.

I. INTRODUCTION

The Dutch Airspace and especially hub Amsterdam Schiphol Airport are operating almost on their maximum levels, this provides challenges that need a wider range of collaboration between stakeholders. The Knowledge Development Centre Mainport Schiphol, which is a collaboration between Air Traffic Control the Netherlands (LVNL), KLM, Schiphol Airport and Ministry of Infrastructure and Water Management (I&W), have launched a first large-scale initiative to objectively perform research in a Centre of Excellence (2017) together with different universities in the Netherlands [1]. The research is transcending organizational boundaries, to create insights and knowledge that individually would be unattainable by the organizations. The research is performed by graduating students (BSc and MSc) the results are used by the aviation industry to move forward.

II. CENTRE OF EXCELLENCE METHODOLOGY

Graduate students research current challenges in the Dutch aviation industry and especially concerned with Schiphol airport. Research proposals determine which graduates are accepted for a position, the graduate primarily determines the research focus based on the questions posed by the organizations. The first major line of research is on capacity

management (figure 1), which is currently the most restrictive feature of the Dutch airspace and Schiphol airport.

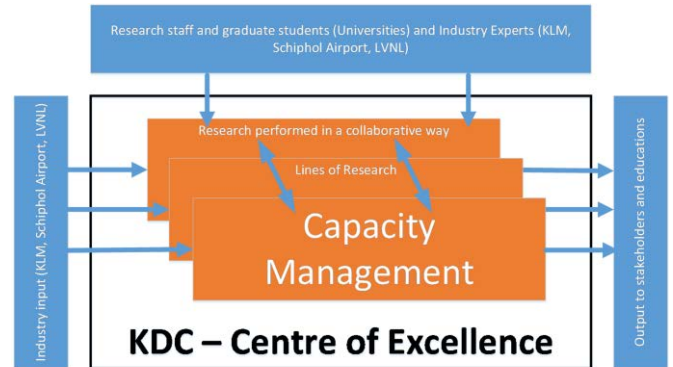


Figure 1. Centre of Excellence setup

A. Related aviation organizations

The major stakeholders at Schiphol airport, provide sector relevant challenges [5] for the graduates to research, access to experts in or outside their organizations and to data that is not always in the public domain. In addition, objective feedback on the research of the graduates without influencing the research direction or outcomes. The research results are part of the long-term developments and goals of the sector and the individual organizations.

B. Related universities

The involved universities together with the Centre of Excellence provide long-term lines of research and supporting researchers. This ensures the creation of results, models or concepts that operationally can be applied by the organizations. In addition, they provide graduate students throughout the year, that perform data analysis, simulations, qualitative fine tuning of the findings and academic access to knowledge unattainable by the organizations by providing supporting research staff. The research results will be used for the academic research departments, inform other staff on current developments and translate to the education.

All research performed is linked to the shared goals of the organizations involved being; performance of the ATM and airport system, efficient use of the airport and airspace resources, maintaining safety levels and operating as planned (plan stability).

C. Governance

Managers from the major stakeholders, represent company interests and guard sector benefits. The CoE is financed by the Dutch government and is located at the LVNL, which is the most neutral stakeholder. Managers are involved in the day-to-day operation within the CoE and are responsible for the continuation.

D. Data Sharing

Researchers and graduates sign an agreement with the LVNL; that covers data sharing and usage protocols in addition publication restrictions for all involved stakeholders. Final results are approved by the managers, before publication. Data access and sharing between organization for research is provided through the respective experts and departments of KLM, Schiphol Airport and LVNL.

III. CENTRE OF EXCELLENCE RESULTS

The past year has led to 15 topics being analyzed, from those the below a selection indicates how these results can affect the stakeholders.

On-Time Performance analysis [5]: during 2015-2017 the on-time performance has gone down, which is not directly related to a worse performance of the system, but is also influenced by the increased traffic numbers, that in turn puts a strain on the system. This is visible in the local A-CDM data, specifically the milestones concerned with the turnaround. The results provide the stakeholders, with the insight to have a discussion to improve the inputs in the A-CDM system.

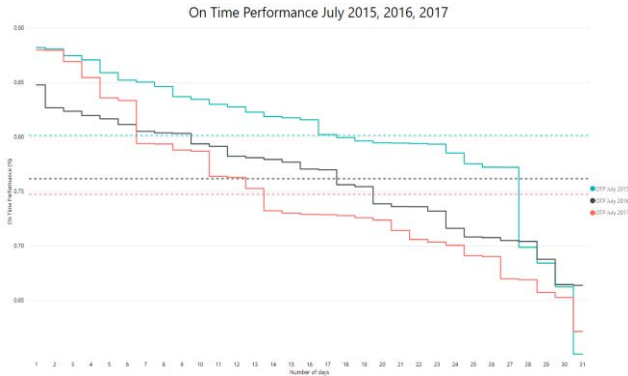


Figure 2. Development of On Time Performance during July 2015, 2016, 2017 (CDM portal Schiphol, 2018)

Level segments in the Dutch airspace analysis [2]: vertical flight efficiency can be improved to reduce ATCo workload and improve fuel efficiency, furthermore the current hand-over conditions with the neighboring air navigation service providers, negatively impact the vertical efficiency of departures from Schiphol airport. In the upcoming airspace restructuring discussion, the identified hotspots and hand-over conditions need to be considered.

Gate occupancy analysis [3]: the impact of airline business models on gate occupancy isn't significant only the business model, but also the aircraft type and increased movements

influence operations at the gate. A renewed insight in the gate planning and usage can support the discussion with the ground handlers and airlines on how their behavior influences the already scarce gate capacity at Schiphol airport.

IV. CONCLUSIONS

The results of the graduate researches provide the aviation industry with the tools/leverage to anticipate or better evaluate future options. In addition, synergy is attained through working together on the same issues, where before separately the workout was done, it now becomes a joint effort to benefit the whole sector. It prevents from focusing on the symptoms and moves towards addressing the root causes of inefficiencies without blaming, but taking responsibility to improve the situation.

Future results especially related to the network will be linked to the SESAR R&D projects, to reflect the Dutch situation to the wider European challenges, and provide the knowledge to the outside.

V. RECOMMENDATIONS

Collaboration on this level achieves more opportunities for the aviation industry than separately researching developments and challenges. The Centre of excellence works because of the involvement of organizations that have a shared vision of the future of aviation in the Netherlands. The benefits gained from the collaboration are not only visible in the shared goals of the organizations but also prepare young professionals for the aviation industry. Any collaboration between universities and industry is able to create new knowledge, insights, input for political discussions or alignment between organizations at an airport. Achieving this requires a shared vision and goals, setting aside commercial objectives and focusing on the industry as a whole.

ACKNOWLEDGMENT

The Centre of excellence is supported and only possible due to the commitment of the following people; Evert Westerveld (Manager Strategy at LVNL), Alina Zelenevska (Manager Centre of Excellence at LVNL), Ferdinand Dijkstra (FerWay consulting), Geert Boosten (Head researcher, Aviation Academy), Coen Vlasblom (KDC Manager at KLM) and Boudewijn Lievegoed (KDC Manager at Schiphol Airport).

Furthermore, appreciation to the Ministry of Infrastructure and Water Management, and BSc graduates Marc Eijkens, Roel Wouters and Martijn Ringelberg for providing their input.

REFERENCES

- [1] Centre of Excellence. (2018). Retrieved from <https://www.kdc-mainport.nl/index.php/nl/centre-of-excellence>
- [2] Eijkens, M. (2018). Analysis of Vertical Flight Trajectory Efficiency. Amsterdam.
- [3] Ringelberg, M. (2018). Airline Strategies' Impact on Gate Occupancy. Amsterdam.
- [4] Westerveld, E. (2018). KDC Research Agenda. Amsterdam.
- [5] Wouters, R. (2018). Impact of Local A-CDM on the Operational Efficiency at Mainport Schiphol. Amsterdam.

PFV: ENAC's Flying Testbed

A new platform for Aeronautical and Air Traffic Control applied research

Jean-Paul Imbert
ENAC
Toulouse, France
jean-paul.imbert@enac.fr

Railane Benhacene
ENAC
Toulouse, France
railane.benhacene@enac.fr

Abstract-- This poster describes ENAC's flying testbed a new platform developed at ENAC for aeronautical and air traffic control applied research.

Keywords- *Flying testbed; human machine interfaces; human factors;*

I. INTRODUCTION

ENAC is internationally recognized as the leading aeronautics and Aviation University in Europe, providing a broad range of training, studies, and research activities. Within ENAC, the ACHIL team, Aeronautical Computer Human Interaction Lab, which operates research simulators for air traffic control and cockpit operations recently added a new string to its bow with an aircraft dedicated to research. Real flight test may help to provide results in a realistic environment for various applications like surveillance, UAV detect and avoid, antennas, human factors, human machine interfaces (HMI), data link communications.

The PFV (French acronym for Flying TestBed), is a Socata TB10 aircraft originally operated for pilot training and now modified to test new concepts or on-board equipment in various research fields. Socata TB10 is a single engine, 4 seats and short haul aircraft, generally used for touring or flight instruction.

Several aircraft are operated as flying testbed in Europe, PFV's specificity is its ability to test light equipment, HMIs or run human factors research with low operation cost and even record data during pilot training. It has been developed by ENAC since 2016 and delivered in September 2018. The PFV has already been used during an experimentation for the ENVISION project (funded by SESAR grant n°783270). ENVISION is an ATM application-oriented research project which aims at making use of ADS-B, CCTV cameras, LIDAR and image processing techniques to provide regional and local airports affordable surface movements surveillance capabilities (<http://www.envision-s2020.eu>).

The PFV has been funded by the city of Toulouse, the Occitanie Region and the French Ministry of Sustainable Development in order to support research in the human-factors' for aviation domain and foster partnerships between industry and academia.

The PFV has been certified by EASA in order to be operated in 3 modes: pilot training, data gathering ('big data' mode) or 'research mode' (right side of the cockpit emptied of original instrumentation and fitted with prototype HMI).

II. DETAILED DESCRIPTION

A. Data acquisition system

The PFV is equipped with a versatile Dewesoft data acquisition system which gathers information coming from avionics systems and sensors. This information can be recorded and delivered in real time via a Wi-Fi network. New equipment can be added and connected to the system or antennas on the payload. New equipment can be attached on the orange tray, energy and network connection are available on the left panel. Additionnal Dewesoft equipments can be connected to the main data computer. In order to guarantee a correct synchronization of data between ground systems and aircraft data, the main computer uses the GPS time stamp of a dedicated GPS device. A gigabit switch provides Ethernet connection as well as synchronization triggers generated by the main computer.



Figure 1. Payload and data acquisition system

B. HMI prototyping area

The right side of the cockpit when in research mode, can be equipped with prototype instrumentation and connected in real time to the data acquisition software. Physiological sensors may also be connected to feed those HMIs. For example, it would be possible to develop new analysis tools for flight instructors or new interfaces for pilots. The latter could be tested in flight while keeping a safety pilot in the left position.

In Figure 2, the left picture shows the available area for prototyping. Several energy and network connectors are available as well as a 10 wire cable connected to the payload area for general purpose input/output (GPIO). The right picture demonstrates the feasibility of a prototyping area setup with two Microsoft Surface tablets, one with the output of Tobii Pro Glasses 2, a wearable eye tracker, the other with gauges fed with data coming from the Dewesoft acquisition system. A 10 wire cable is also available under pilot's seat in order to provide GPIO or energy to devices like shakers.



Figure 2. HMI prototyping area in the right side of cockpit

C. Additional antennas

The PFV allows to test new types of antenna, several dedicated spaces have been made in its structure for this purpose (figure 3 top) and coax cables are connected to the cargo hold. There is also one multiband GPS antenna (figure 3 bottom) available per wingtip for applications like attitude assessment.



Figure 3. Additional GPS antennas and spare rooms for new one

D. Stereoscopic camera system

Two high performance monochrome cameras have been placed one per wingtip for detect and avoid applications or precise localization and mapping.



Figure 4. Wingtip cameras

III. DATA ACQUISITION AND REAL TIME DELIVERY

All the data coming from systems like the avionics (GPS, XPDR, ADS-B in, EFIS), the engine, the IMU (inertial measurement unit), the pilot's command (via sensors), the attitude indicator are recorded and broadcasted by the data acquisition system in real time at high speed. The broadcasted data can be displayed by the DewesoftX3 software or delivered to third party HMI via a network connection to the data acquisition system. The on board recording device has a 400 flight hour capacity making it useable for 'big data' and training operation modes. If video from both camera is added, 70 flight hour can be recorded.

IV. AIRCRAFT OPERATION

The PFV is operated and maintained by ENAC personnel at one of ENAC's flight school in a small airport near Toulouse. Providing that flight tests are compliant with the certifications modes: 'big data' (data gathering with original instrumentation) or 'research' (data gathering with prototype instrumentation) there is no need of special flight permit to be delivered by the civil aviation authorities. In research mode, a 'safety pilot' is mandatory. ENAC's maintenance facility has the ability to realize modifications on the PFV and finalize the necessary certification process.



Figure 5. PFV, ENAC's flying testbed

V. PARTNERSHIPS

The PFV is designed as a versatile tool, it already offers a lot of possibilities for applied research in various academic fields. The ACHIL team is open to collaboration with academic and industrial partners with the PFV.

ACKNOWLEDGMENT

The PFV has been funded by the city of Toulouse, the Occitanie Region and the French Ministry of Sustainable development within a CPER contract (Contrat de Plan Etat Region)

CLear Air Situation for uaS

Fabien Bonneval, Jim Sharples, Yannick Jestin
UAV lab,
ENAC
Toulouse, France
firstname.name@enac.fr

Mohammed Jahangir
Aveillant
Cambridge, UK
mohammed.jahangir@aveillant.com

Abstract—CLASS (CLear Air Situation for uaS) merges existing technologies to build core functions of U-Space. This research increases the maturity level of the main technologies required for the surveillance of drone traffic. Use Case Scenarios and Key Performance Indicators (KPIs) are defined to assess the performance of future U-Space systems. The project will also provide baseline results through live and simulated trials.

Keywords—CLASS; UTM; U-Space; Tracking; Deconfliction; flights

I. INTRODUCTION

Drone technology is on the rise and the number of drones in the air increases at a rapid pace. Unfortunately, drones are hard to detect and they often fly literally below the radar. As a result, the chances of conflicts between drones and manned air traffic (or between drones themselves) would be very high without the current restrictive regulation. However, the different stakeholders are pushing to ease this regulation. This can only be allowed if a sufficient level of safety can be guaranteed.

CLASS is the acronym for CLear Air Situation for uaS, and is part of a Horizon 2020 SESAR-1-2016 call. The CLASS project merges existing technologies to build the core functions of an Unmanned Traffic Management System (UTMS). This research increases the maturity level of the main technologies required for surveillance of Unmanned Aerial System (UAS, also known as drone) traffic. CLASS also define use case scenarios and KPIs and will provide a baseline to assess the performance of future U-Space systems.

The CLASS consortium is composed by Airbus (France), Aveillant (England), ENAC (France), NTNU (Norway) and Unifly (Belgium).

CLASS is a sibling project of CORUS [1], which aims at defining the Concepts of Operations for UAS in U-Space.

II. THE CLASS PROJECT

CLASS functionalities include real-time tracking and display of both cooperative and non-cooperative drones.. Drones that transmit their location themselves are called cooperative, whereas for non-cooperative drones the locations are observed and tracked by the external system. In both cases, relevant aeronautical data is aggregated and the data from

multiple trackers (both on the drones and on the ground-based systems) is merged through data fusion so that the location of all drones in the airspace can be known and displayed.

Based on these functionalities, a real-time centralized UTMS is being developed. This platform will propose an overall view of both the planned and the current real-time UAS traffic situation.

This information will be centralised in real-time in a UTMS to create an overall solution with advanced functions.

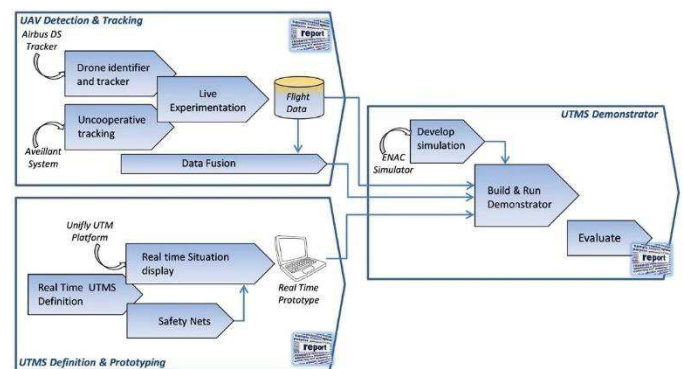


Figure 1 The CLASS architecture

III. REQUIREMENTS AND EVALUATION METRICS

A wide set of stakeholders' requirements has been gathered in a workshop and translated into six design scenarios and 17 preliminary Key Performance Areas (KPA) [2].

The scenarios have been flown during live trials. Furthermore, simulations incorporating real flight data and modelling more challenging air traffic will be run. The KPAs will be used to assess the performance of the end system.

The six scenarios are:

- GNSS failure leading to intrusion in an airport
- Conflicts in an emergency situation
- Instrument Landing System calibration
- Aerial work on high voltage lines

- Gliding rogue drone
- Urban pollution sampling

The table 1 shows an extract of the KPIs relative to accuracy, detectability and false classification

TABLE 1 KPIs EXTRACT

KPI Name	KPI Definition
Horizontal Position Error (ePosH)	$RMS(pos_H^T - pos_H^R)$ pos_H^T = Tracker Horizontal position pos_H^R = Reference Horizontal position
Vertical Position Error (ePosV)	$RMS(pos_V^T - pos_V^R)$ pos_V^T = Tracker Vertical position pos_V^R = Reference Vertical position
Prob of Update (PU)	$\frac{N_{DD}^T}{N_{DD}^R}$ N_{DD}^T = Drone Detections from Tracker N_{DD}^R = Total Drone Detections from Reference
Mean Gap per track (mGAP)	$\frac{1 - PU}{N_{DT}^T}$ N_{DT}^T = Drone Tracks from tracker
False Positive Rate (FPR)	$\frac{N_{AT}^T - N_{DT}^T}{\Delta t}$ N_{AT}^T = All tracks from tracker Δt = time duration

IV. IMPLEMENTATION

CLASS is merging and increasing the maturity level of existing technologies [3]:

- Airbus' Drone-It! cooperative surveillance system emitting on L band (1525 → 1625 MHz)
- Aveillant's radar (non-cooperative surveillance system) can detect small drones up to 5km away
- NTNU's Data fusion between cooperative and non-cooperative surveillance systems
- Unifly's Real-time UTMS

The drones have been built and flown by ENAC with its Paparazzi UAV [4] open source autopilot, capable of fully autonomous flight.

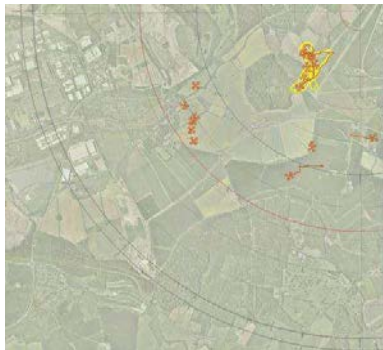


Figure 2 Aveillant's radar output

V. TESTING

The project includes two real flight campaigns based on the scenarios and KPIs:

- June 2018: training the radar with 2 fixed wing drones. Paparazzi logs provide the reference data with an horizontal accuracy of 3m.
- October 2018: Integration of Drone-It and Unifly systems to the CLASS architecture

The results obtained are currently being used to design the data fusion algorithm.



Figure 3 ENAC's "Dark Knight" drone

VI. DECONFLICTION

Deconfliction is not a core CLASS objective, nevertheless Airbus is working on a drone-drone tactical deconfliction algorithm.

In CLASS context, deconfliction relies on the tracking service and takes place at a tactical level - i.e. during the flight - and before Detect and Avoid intervention.

The Airbus algorithm

- is NOT an onboard collision avoidance system.
- will be capable of predicting more than 1,000 trajectories per seconds.
- Drone information is crucial (characteristics, navigation, constraints, weight, etc.).
- The notion of "conflict" needs to be defined further.

REFERENCES

- [1] SESAR Joint Undertaking, CORUS, <https://www.sesarju.eu/projects/corus>
- [2] CLASS Consortium, "D1.1 – Scenarios and KPIs for the U-Space System Demonstration", 2018
- [3] CLASS Consortium, "D2.1 - Definition of the cooperative and uncooperative surveillance systems", 2018
- [4] Paparazzi UAV, <https://paparazziuav.o>

Learning Air Traffic Controller Strategies with Demonstration-based and Physiological Feedback

Duc-Thinh Pham¹, Ngoc Phu Tran², Sim Kuan Goh³, Ma Chunyao⁴, Sameer Alam⁵, Vu Duong⁶

Air Traffic Management Research Institute, School of Mechanical and Aerospace Engineering

Nanyang Technological University, Singapore

Email: {¹dtpham | ²phutran | ³skgoh | ⁵sameeralam | ⁶vu.duong}@ntu.edu.sg, ⁴M180146@e.ntu.edu.sg

Abstract—In this research, we demonstrate an Artificial Intelligence framework that is able to learn conflict resolution strategies from human Air Traffic Controllers and then employ such knowledge in developing conflict resolution advisories. The proposed framework is designed to assist reinforcement learning, using conflict resolution actions and brain signals. By involving human-in-the-loop in the training, the Artificial Intelligence framework is expected to generate conflict resolutions advisories with high acceptability. Our preliminary results have shown the ability of our framework in learning Air Traffic Controllers' strategy and providing human-like resolutions.

I. INTRODUCTION

The ultimate function of an air traffic control (ATC) system is to maintain a safe separation distance, both vertically and horizontally, between any two aircraft at all time. To assist Air Traffic Controllers (ATCOs) in accomplishing this crucial task, some advanced ATC systems are equipped with conflict resolution tools to provide the ATCOs with resolution advisory. As air traffic is continuously growing with the increasing air passenger demand [1], conflict resolution advisory systems are gaining in importance in aiding controllers to deal with complex conflict scenarios in increasingly busy airspace.

Many approaches in literature have been proposed for conflict resolution systems [2]–[4]; some of them are able to resolve very complex conflict scenarios. Although the mathematical models for automatic conflict resolution are continuously improved, the final decisions are always made by human ATCOs and such decisions usually involve the ATCO's strategy of managing the overall traffic flow. For a conflict resolution advisory to be accepted by human controllers, it must reflect the strategy of human ATCOs in resolving conflict. This requires the conflict resolution algorithms to be capable of learning and understanding the ATCO strategy in managing such situations. Unfortunately, to our best knowledge, none of the available automatic conflict resolution algorithms possesses this capability.

In this study, we build and demonstrate an Artificial Intelligence (AI) agent that is able to learn conflict resolution strategy from human ATCOs and then employ such knowledge in developing conflict resolution advisories. The proposed system is designed to support reinforcement learning with demonstration-based and neural feedback from ATCOs. By involving human-in-the-loop, our AI agent is expected to generate conflict resolutions advisories that are highly accepted by ATCOs.

II. METHODOLOGY

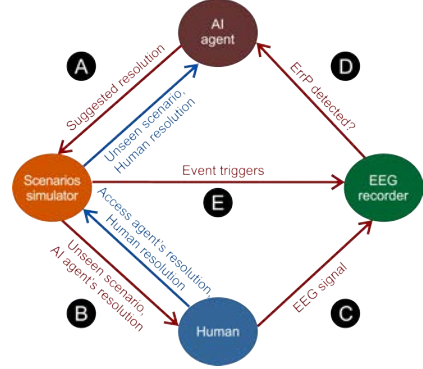


Figure 1. Proposed framework for integration of brain computer interface, 3D-simulator and AI learning algorithm.

An experienced ATCO uses a variety of conflict resolution strategies, which may depend upon complexity of the conflict, neighbouring traffic, airways structure, traffic flow, sector geometry, secondary conflicts, Letters of Agreement etc. The *strategy* can be defined as a set of fuzzy rules which show the preferences for a particular set of actions in a given situation.

Learning human strategy is a challenging work which involve two main parts: capturing the preferences and then applying an appropriate learning architecture to model them. Firstly, human preferences can be reflected implicitly via their internal brain activities or explicitly via their recorded actions/decisions which will be captured and fused to enhance the learning process. Secondly, because of dynamic airspace environment and continuous action space, we propose using Deep Deterministic Policy Gradient (DDPG) [5] to not only learn human preferences including environment feedback, but also predict the corresponding actions for conflict scenarios.

In general, as illustrated in Figure 1, our proposed framework is an integration of brain computer interface, 3D-simulator and AI learning algorithm. The 3D-simulator with interactive interface is developed to collect data in interaction with human, Electroencephalographic (EEG) device and act as the environment in interaction with AI Agent. In operation, the AI agent, driven by reinforcement learning algorithm, tries to suggest a resolution for a given scenario. The emergence of human strategy is triggered by requiring human to evaluate agent's resolution and provide his own resolution for that

scenario, through an interactive human-computer interface. An EEG brain-computer interface (BCI) is also established to capture brain's wave patterns, error-related potential (ErrP) [6], when human is evaluating agent's resolution. Through this process, these pattern is used to transfer the acceptability of the agent's resolution as part of feedback mechanism to improve its learning. As the result, AI Agent will learn human strategy and suggest appropriate resolution for given conflict which reflects ATCO preferences.

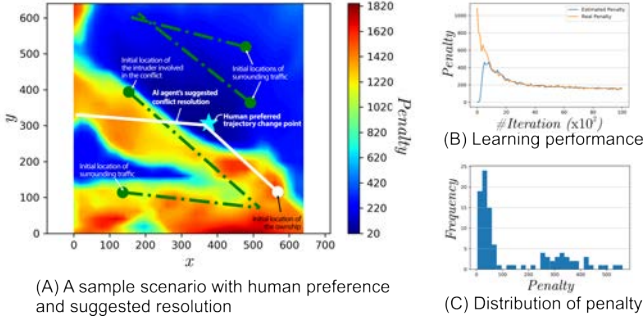


Figure 2. Illustrating experimental results for learning from human preferences to resolve conflicts

III. PRELIMINARY RESULTS

The proposed model can estimate the distribution of action-value function for unseen scenario reflecting human strategy considering surrounding traffic. The experiment is conducted for training AI Agent with 400 pairs (*scenario*, *preference action*) for learning and 100 pairs for evaluation. *Scenario* includes 5 flights with one Ownship and 4 Intruders with at least one conflict between Ownship and Intruders. The reward function is non-negative, hence the smaller the score (≥ 0) is, the better the position as conflict resolution is. As shown in Figure 2b, after 2,000 training steps, the estimated rewards and real rewards on test cases are converged that means the AI Agent can approximate the reward function reflecting human strategy. In Figure 2a, the AI Agent shows highest score around human resolution (star symbol “*”) for unseen scenario considering surrounding traffic. Furthermore, as shown in Figure 2c, 65% of agent's suggested resolutions receive low penalty (less than 100), which means these resolutions highly match the human preferred resolutions. From the experiment result, our model is able to learn not only the preference solutions but also the in-feasible solutions or feedback from environment. Although more experiments are needed to access the performance of proposed model, our framework is promising to efficiently harness ErrP and Preference Action as human feedback. The proposed AI Agent is also able to generalize the human preference function and human-like action prediction for 3D scenario to capture and reproduce hidden strategy from data.

IV. CONTENT OF DEMONSTRATION

The experimental setup is shown in Figure 3, in which a human subject, who is equipped with a EEG recording device,

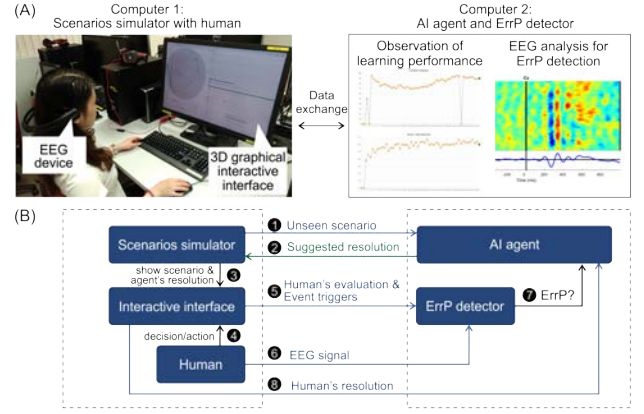


Figure 3. (A) The demonstration setup consisting of 2 computers exchanging data: Computer 1 runs the simulator for human interaction and Computer 2 hosts the AI agent and ErrP detector. ErrP signal was generated using dataset in [6]. (B) Data flow between two computers during one experimental trial. The circled numbers show sequence of data being transmitted.

is interacting with our air traffic simulator. An experimental trial begins when the simulator sends an unseen scenario (the scenario) to the AI agent and the agent replies with a suggested resolution. The scenario and the suggested resolution are then presented to the subject. Subject starts assessing the proposed solution by AI and decides whether the solution is acceptable. In case the subject rejects the AI's resolution, subject will be asked to provide a resolution. During the interaction, the simulator and EEG system decode human behavioural and physiological (i.e. ErrP) data respectively. The data is subsequently fed to adapt AI. Our experimental design closely resembles a two-player game where human distinguishes good and bad solutions while AI generates good resolutions with high human acceptability.

V. ACKNOWLEDGEMENT

This research has been partially supported under Air Traffic Management Research Institute (NTU-CAAS) Grant No. M4062429.052

REFERENCES

- [1] "IATA forecasts passenger demand to double over 20 years," <https://www.iata.org/pressroom/pr/Pages/2016-10-18-02.aspx>, october 2016, accessed: 2018-10-02.
- [2] J. K. Kuchar and L. C. Yang, "A review of conflict detection and resolution modeling methods," *IEEE Transactions on Intelligent Transportation Systems*, vol. 1, no. 4, pp. 179–189, 2000.
- [3] C. Allignol, N. Barnier, N. Durand, and J.-M. Alliot, "A new framework for solving en-routes conflicts," in *ATM 2013, 10th USA/Europe Air Traffic Management Research and Development Seminar*, 2013, Conference Proceedings, pp. pp 1–9.
- [4] M. Radanovic, M. A. Piera Eroles, T. Koca, and J. J. Ramos Gonzalez, "Surrounding traffic complexity analysis for efficient and stable conflict resolution," *Transportation Research Part C: Emerging Technologies*, vol. 95, pp. 105–124, 2018.
- [5] T. P. Lillicrap, J. J. Hunt, A. Pritzel, N. Heess, T. Erez, Y. Tassa, D. Silver, and D. Wierstra, "Continuous control with deep reinforcement learning," *arXiv preprint arXiv:1509.02971*, 2015.
- [6] R. Chavarriaga and J. d. R. Millán, "Learning from eeg error-related potentials in noninvasive brain-computer interfaces," *IEEE transactions on neural systems and rehabilitation engineering*, vol. 18, no. 4, pp. 381–388, 2010.

ADAPT - Advanced Prediction Models for Trajectory-Based Operations (TBO)

T. Bolić, L. Castelli, G. Scaini
Università degli Studi di Trieste
Trieste, Italy

R. van den Brandt, M. Mitici, R.
Verbeek
TU Delft
Delft, Netherlands

A. Cook, L. Delgado, G. Gurtner
University of Westminster
London, United Kingdom

G. Frau
Deep Blue
Rome, Italy

G. Pappalardo, R. N. Mantegna, S. Miccichè
Università degli Studi di Palermo
Palermo, Italy

Abstract—Presentation of the concept, data requirements and preliminary results of the ADAPT project.

Keywords—strategic flight planning; flexibility; metrics; integer programming models; simulation; ELSA; SATURN

I. CONCEPT

The scope of ADAPT is to propose a set of methods and tools (a “solution”) at the strategic and/or pre-tactical level of network management that is conducive to trajectory-based operations, which clearly demonstrates the flexibility, information exchange responsibilities, and benefits for all the stakeholders. The aim of the project is to adapt, create and test models and metrics that enable strategic planning (early information sharing), by providing information on flight flexibility (through the assignment of time windows¹ (TWs)) and network hotspots, which can eventually be integrated into the Network Operations Plan and serve as a basis for stakeholder collaboration. The ADAPT project consists of three main activities: (i) Development of the ADAPT strategic solution (ongoing); (ii) Tactical assessment (preparatory tasks), and (iii) Visualisation (still to start).

In turn, the ADAPT strategic solution development consists of three phases: (i) the formulation and implementation of a deterministic model (European Strategic Flight Planning (EFPS) model) to assign flight trajectories and associated time windows at the strategic level, (ii) the assessment of the expected economic loss during disturbances (e.g., flight delays, bad weather), and (iii) the definition of possible actions to mitigate detected expected demand and capacity imbalances, on the day of operations. Phases (i) and (ii) cover the definition of the ADAPT solution, while in phase (iii) the outputs are used to devise mitigation actions in order to improve the situation, if possible.

The ESFP model builds on two deterministic, integer programming models. Considering a busy day in the European network, and the changing sectorisation, the aim of the first model is to assign a minimum cost trajectory for each scheduled flight, in such a way that the nominal capacities of the network are respected. When all flights have a trajectory and departure time assigned, these become inputs of a second integer programming model, the aim of which is to determine the flexibility (in terms of TWs) of all flights and the critical spots in the network [1]. This second model uses departure times as the starting position of TWs, and the objective is to guarantee the largest flexibility by maximising the total duration of all TWs. The output of this second model are the trajectories, assigned TWs and the hotspots in the network.

II. DATA REQUIREMENTS

In order to both develop and validate ADAPT models, extensive amounts of historical data are needed: the network infrastructure, ATM status, traffic (trajectories and sector crossings), flight costs (strategic and tactical), regulations, weather. The main data sources are DDR2 (network infrastructure, traffic), ATFM Network Statistics (for ATFM regulations), a University of Westminster report (for flight and delay costs) [2], and ECMWF, the European Centre for Medium-Range Weather Forecasts (wind ensembles).

III. PRELIMINARY RESULTS

To be able to assess benefits, a baseline is compared with the ADAPT solution scenario (application of ADAPT models). The baseline scenario is obtained by running the first ESFP strategic model, but with unconstrained capacities, which is consistent with the current practice of not considering capacity in the strategic phase. The baseline scenario de facto corresponds to a

This project has received funding from the SESAR Joint Undertaking under the European Union’s Horizon 2020 research and innovation programme under grant agreement 783264.

¹A time window is a time interval describing the flexibility (in time dimension) of a trajectory. A time window indicates how “late” (with respect to declared timing of the trajectory) a flight can be and still not create capacity-demand imbalances in the network.

simple assignment of routes of minimum cost (or minimum duration), disregarding capacities.

In the solution scenario both ESFP models are applied, for the whole day, over the entire European network. The models process 29 535 flights, over 22 862 sector-hours. The optimal solution is found in less than 3 minutes, with the optimality gap less than 0.1%. In the baseline, capacity is breached in a number of sector-hours, while that is not the case in the solution scenario.

Furthermore, we find that a vast majority of flights, apart from not causing capacity imbalance - is flexible - having time windows of 15 minutes. A bit more than 5000 flights have TWs lower than 15 minutes (so called critical flights), out of which only about 600 flights are very constrained (TW of 1 minute), as can be seen in Fig. 1. Fig. 2 depicts a possible use of ADAPT results - a trajectory assigned to a flight from LGAV to LFPO, departing at 08:30, has to be on time, along the entire route as it has a TW of 1 minutes, and there are 3 sectors along the trajectory, the capacity of which is constraining this particular flight.

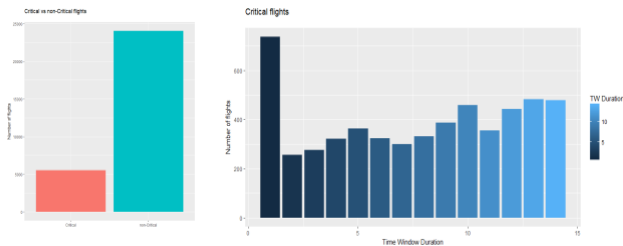


Figure 1. Critical versus non-critical flights and the distribution of flights across TWs of duration <15 minutes.

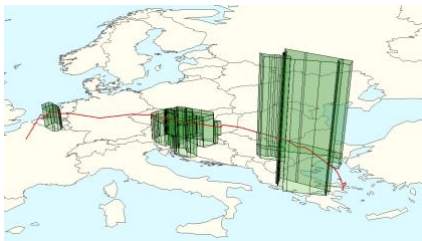


Figure 2. Flight LGAV-LFPO, TW of 1 minute and the constraining sectors (visualisation source: Eurocontrol's NEST).

IV. NEXT STEPS

To assess the ESFP models, the ADAPT project will:

1) Define metrics in support of the development and assessment of the ADAPT solution:

a) A (strategic) measure of the (economic) risk of hotspots, to give information on how likely a hotspot identified strategically can be one on the day of operations, and what consequences it would bring.

b) Statistically robust metrics on sector level to be used in the assessment efforts. In this respect three metrics are being considered: (i) **di-FORK**: to measure the deviations from the original flight plans at the trajectory level, and using it to identify portions of airspace where deviations occur more or less frequently than expected. (ii) **Complexity metrics**: use of metrics that measure congestion in relation to several operational aspects of air traffic management. (iii) **Percolation**:

adaptation of a technique used to investigate congestion at the level of urban mobility to the air traffic management context.

2) Provide a thorough assessment (validation) of the ADAPT solution in the tactical setting, from two points of view:

a) **Network-wide assessment**, where simulations of the entire European network will be performed to understand whether the proposed TWs are meaningful from an operational point of view. This will be done by using the ADAPT strategic solution trajectories as an input to the tactical layer of the ELSA [3] simulator to identify whether the conflict detection and resolution operations can be performed within the assigned TWs, and how frequent are they.

b) **Flight-centric assessment**, where fuel consumption and arrival delay of individual flights are considered. We determine the influence of weather conditions on the punctuality of the flight at sector entry. We consider ensemble wind forecasts, from ECMWF available 1 day in advance of the day of the flight execution. A forecast consists of 50 ensembles which are created by running the forecast with slightly different initial conditions.

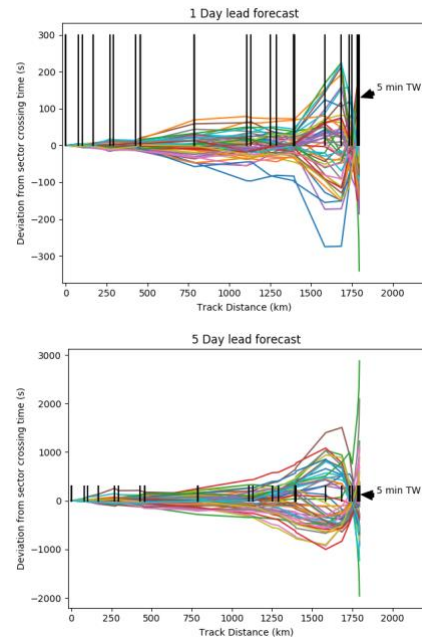


Figure 3. Deviation from sector crossing time in case of 1 day (top) and 5 day lead forecast.

Fig. 3 shows the deviations from the nominal sector entry times as a function of the track length under the influence of uncertainty in the weather, relative to a TW of 5 minutes for each sector entry (vertical, black lines). For a forecast of 1 day before the day of the execution, a TW with width of 5 minutes is sufficient to accommodate the uncertainty associated with the wind forecast.

REFERENCES

- [1] T. Bolić, L. Castelli, L. Corolli, D. Rigonat, Reducing ATFM delays through Strategic Flight Planning, Transp. Res. Part E, 98, 42-59, 2017.
- [2] A. J. Cook, G. Tanner, European airline delay cost reference values. EUROCONTROL Performance Review Unit, 2015.
- [3] G. Gurtner, C. Bongiorno, M. Ducci, S. Micciché, An Empirically grounded Agent Based simulator for the Air Traffic Management in the SESAR scenario, J. Air Transport Management, 59, 26-43, 2017.

Route Charging per Airport-pair in Europe - How to come up with Unit Rates?

Impacts of traffic distribution over charging zones

Goran Pavlovic

Division of Airports and Air Traffic Safety

University of Belgrade – Faculty of Transport and Traffic Engineering

Belgrade, Serbia

g.pavlovic@sf.bg.ac.rs

I. INTRODUCTION

The provision of air navigation services (ANS) requires substantial investments in labor and equipment. The costs of providing ANS are borne by airspace users through air navigation charges and, subsequently, by passengers through increased ticket prices. According to data from 2013, the share of air navigation charges in total operating cost of European airlines was approx. 6% [1].

The European Air Traffic Management (ATM) system is highly fragmented, i.e. it consists of 37 Air Navigation Service Providers (ANSP) whose areas of responsibility are, in most cases, limited to national borders. Indeed, it is argued that fragmentation in Europe “mainly arises from the organization of ANS at the state level” and “increases the cost of providing and enhancing capacity” [2].

Air navigation charges for the services provided in the en-route phase of the flight are called route charges. Current route charging system in Europe is adapted to this fragmented ATM system and is intended to cover the ANS provision costs at the level of individual ANSPs. It is based on unit rates defined for different charging zones which are mostly aligned with the areas of responsibility of individual ANSPs. Unit rates are set for a fixed period and are calculated by dividing the forecast cost-base of the charging zone concerned for the reference year by the forecast number of service units to be generated in the charging zone during the same year [3].

Difference in the unit rates has led to a trend of aircraft taking detours around expensive charging zones, resulting in traffic shifts and additional fuel consumption and emissions [4].

One possible way of solving this problem is the introduction of the airport-pair charging (APC) system, where the total amount of route charges (or at least the unit rate) between the observed airport pair would not depend on the chosen flight route, i.e. charging zones overflown. Although this idea is not new to the ATM community, so far there have been very little attempts to closely define the methodology of its implementation, particularly in the context of fragmented ANS provision. One of the recent publications dealing with

airport-pair charging in Europe is [5]. The authors proposed a charging method called FRIDAY (Fixed Rate Incorporating Dynamic Allocation for optimal Yield), according to which route charges are calculated using the section lengths along the great circle line, which subsequent dynamic allocation of the collected revenue between the charging zones.

Assuming that fragmented ATM provision in Europe will remain in future, the main challenge with APC is to define airport-pair unit rates (APUR) so as to recover individual ANSP costs. A naive and simple solution could be the “weighted arithmetic mean” formula:

$$APUR = \sum_{i=1}^n w_i * t_i \quad \sum_{i=1}^n w_i = 1$$

where:

w_i – estimated relative share of ANSP i in airport-pair service provision;

t_i – unit rate of ANSP i (as calculated today according to CRCO methodology);

It is obvious that such defined APUR would depend on the traffic distribution over the charging zones, i.e. the APUR value would be influenced by individual unit rates of ANSPs overflown and by the level of ATM fragmentation between the observed airport pair.

The poster aims at providing insight into the scope of the impact of fragmented ANS provision on unit rates for different airport pairs, flight distances and dominant traffic flows to/from Europe.

II. AIRPORT-PAIR UNIT RATE VARIATION – EMPIRICAL ANALYSIS¹

An analysis of the APUR variation on a daily² level was conducted. Two busy summer months of traffic were analyzed

¹ The author is aware of the fact that one of the factors influencing route choice and subsequently traffic distribution over charging zones would disappear with the introduction of APC. However, due to well-known difficulties of estimating airline choice behavior in the absence of airline business data, this analysis is based on historical flights and represents a sort of “worst-case” scenario.

(June and July 2016), with a total of 1,999,713 flights operated between approximately 79,000 airport-pairs.

Last filed flight trajectories were obtained from EUROCONTROL DDR2 (Demand Data Repository) database. Circular flights, as well as airport-pairs with less than 10 days of traffic within those two months were discarded from the analysis. The remaining dataset consists of 1,768,992 flights and 20,677 airport pairs which represents 88% of the initial traffic demand. For each of the 61 days analyzed, ANSPs' shares in airport-pair service provision (based on CRCO service units) and associated APURs were calculated. Individual ANSP unit rates were taken from June 2016.

As expected, APUR values are higher in the areas of more expensive charging zones, as seen in Figure 1 below. For example, the mean APUR for London Heathrow - Madrid Barajas pair is 72.47EUR, while for Warsaw Chopin - Istanbul Ataturk it equals only 34.38EUR.

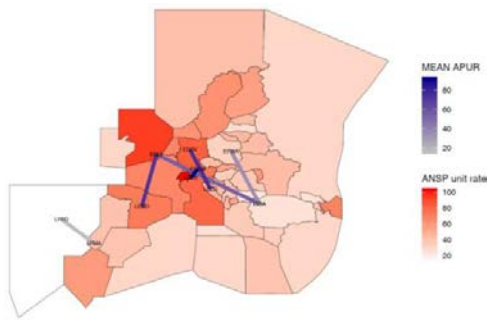


Figure 1. Geographical differences in APUR (intra-european airport-pairs)

Figure 2 shows the standard deviation (STD) of the APUR for intra-European airport-pairs. Each dot in the plot corresponds to one airport-pair. Interestingly, most of the airport-pairs in Europe would have a very low variation of the APUR, with median value at merely 0.15EUR, as seen in Figure 2 (right). However, there are some extreme examples of airport-pairs for which the standard deviation of APUR goes above 15 or even 20EUR. Not suprisingly, these airport pairs are mostly aligned with the boundaries between the adjacent charging zones with significant differences in unit rates.

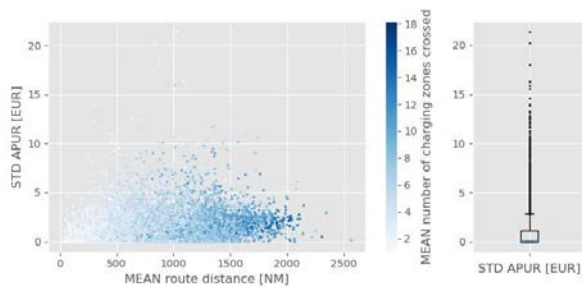


Figure 2. Standard deviation of the APUR (intra-european airport-pairs)

APUR variation generally increases with the route distance and the number of charging zones overflowed. This effect is evident in Figure 3 below.

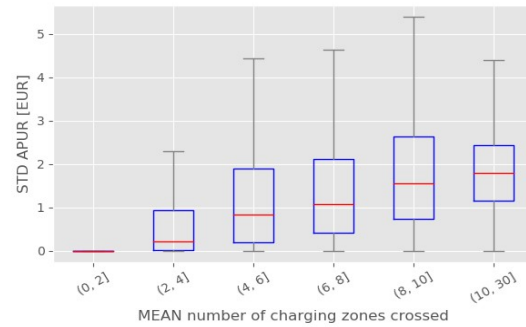


Figure 3. Impact of the number of charging zones overflowed on APUR variation (intra-european airport-pairs)

Figure 4 shows the variation of APUR for a few dominant traffic flows to/from Europe. It is notable that airport pairs between American continents and Europe have quite large APUR variation. This could be explained by substantial spatial dispersion of flights over the Atlantic to take advantage of favourable winds, as well as by the existence of some obvious interfaces between expensive and cheap charging zones on the way to/from Europe. Middle East-Europe flow has similar APUR variation like intra-European airport pairs, which could be explained by shorter flight distance and the convergence of flight routes over Turkey due to Syria crisis

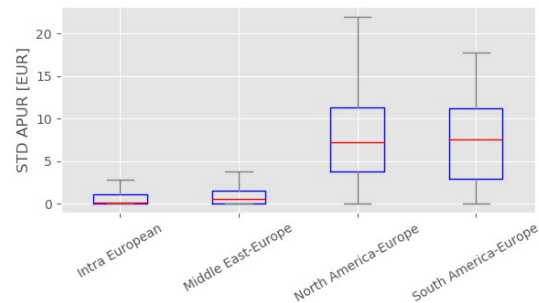


Figure 4. APUR variation for selected dominant flows to/from Europe

REFERENCES

- [1] EUROCONTROL PRC, 2015. Performance Review Report: An Assessment of Air Traffic Management in Europe during the Calendar Year 2014
- [2] Helios for EUROCONTROL Performance Review Commission, 2006. The impact of fragmentation in European ATM/CNS.
- [3] "CRCO customer guide to charges", EUROCONTROL Central Route Charging Office (CRCO), Brussels, February 2017
- [4] L. Delgado, "European route choice determinants". 11th USA/Europe ATM R&D Seminar, 2015, Lisbon, Portugal
- [5] Verbeek, R.J.D. and Visser, H.G., 2016. Why aircraft will fly more fuel-efficiently on FRIDAY: The FRIDAY route charges method. In 7th International Conference on Research in Air Transportation

² Daily variation in this context is used only to assess the scope of potential impact on the unit rate. Once defined, unit rates would certainly have a longer period of validity.

Augmented Reality (AR) for ATCO Supervisors

Per Larsson
Linköping University, Sweden
per.g.larsson@liu.se

Jonas Unger
Linköping University, Sweden
jonas.unger@liu.se

Jonas Lundberg
Linköping University, Sweden
jonas.lundberg@liu.se

Billy Josefsson
LFV Air Navigation
Services of Sweden
billy.josefsson@lfv.se

Abstract—The performance of an air traffic controller (ATCO) is tightly coupled with his or hers momentary emotional and physiological status. In this pilot study, we evaluate the use of advanced visualization methods using augmented/mixed reality (AR) for ATCO supervisors. The goal is to measure, collect and visualize data such as pulse, breathing rhythms and body temperature. The central aspect of this pilot study is to understand how information encoded as text, geometric shapes and color can be used in AR application to enable the supervisor to improve their assessment of ATCO performance, and the extension to working remotely from a completely different site.

Keywords—Augmented Reality, visualization, computer graphics

SYSTEMS OVERVIEW

This study investigates how information based on measured data such as heart rate, breathing patterns and body temperature can be visualized for the ATCO supervisor in order to monitor the ATCO's status during operation. This project have designed and implemented a proof of concept pipeline demonstrating how this problem can be solved using AR, and the technical challenges involved.

Pipeline - The pipeline consists of three main components: scene digitization, on-line recording of video and data measurements, and AR visualization.

In a first step, a coarse 3D model of the scene is built using photogrammetry or time of flight laser scanning, LIDAR, as illustrated in Figure 1 and described in [Unger et al. 2015]. The purpose of the 3D model, or point cloud is to map the workstation of each ATCO in 3D so that the measured information can be anchored in 3D and into the 360°-video used in the on-line capture. This enables rendering of virtual 3D objects representing the measured information into the captured 360°-video stream(s) in real-time. The on-line capture system consists of one or more 360°-video cameras monitoring the ATCOs and their working environment. The location and orientation of the 360°-video cameras are recovered using camera calibration techniques and mapped to the captured 3D model.

Given the scanned 3D model of the environment and the registered 360°-video cameras the information describing the state of the ATCOs is then visualized using different geometric shapes and colors, and rendered into the captured video sequences, see [Kronander et al. 2015]. The 360°-video allows the supervisor to see both the active ATCOs and the status information from a birds-eye-view with unrestricted view directions from the location of each of the cameras. The



Figure 1. A visualization of the 3D scanned environment point cloud and camera locations (spheres).



Figure 2. AR view that shows the different data sources visualized with different geometry.

visualization can be done using both head-mounted-display systems as well as conventional monitors.

Case study - As a case study, the project scanned and created AR visualizations from the air traffic control center (ATCC) at Sturup airport in Sweden, see Figure 2. The initial experiments and the ongoing evaluations have shown that AR indeed has a very strong potential to be used as a tool for ATCO supervisors. We also see applications of the AR techniques developed within the project for remote surveillance.

ACKNOWLEDGMENT

This study was funded by the Swedish Transport Administration and the LFV Air Navigation Services of Sweden through the project "Förstärkt verklighet för skiftledare".

REFERENCES

- [1] Jonas Unger, Andrew Gardner, Per Larsson, and Francesco Banterle. Capturing reality for computer graphics applications. In *Proceeding SA '15 SIGGRAPH Asia 2015 Courses, Article No. 7*, 2015.
- [2] Joel Kronander, Francesco Banterle, Andrew Gardner, Ehsan Miandji, and Jonas Unger. Photorealistic rendering of mixed reality scenes. *Computer Graphics Forum special issue Proceedings of Eurographics '15*, 34(2): 643 - 665, May, 2015.

No More Surprises: Stand Assignment Algorithm with Likelihood of Turnaround Time Deviation

Generating delay-aware stand assignment, optimized for the desired management perspectives

Margarita Bagamanova
Telecommunications and Systems Engineering
Universidad Autonoma de Barcelona
Barcelona, Spain
margarita.bagamanova@uab.cat

Miguel Mujica Mota
Aviation Academy
Amsterdam University of Applied Sciences
Amsterdam, the Netherlands
m.mujica.mota@hva.nl

Abstract—Airport management is frequently faced with a problem of assigning flights to available stands and parking positions in the most economical way that would comply with airline policies and suffer minimum changes due to any operational disruptions. This work presents a novel approach to the most common airport problem – efficient stand assignment. The described algorithm combines benefits of data-mining and metaheuristic approaches and generates qualitative solutions, aware of delay trends and airport performance perturbations. The presented work provides promising solutions from the starting moments of computation, in addition, it delivers to the airport stakeholders delay-aware stand assignment, and facilitates the estimation of risk and consequences of any operational disruptions on the slot adherence

Keywords- risk; airports; airspace; congestion; stand assignment; turn-round time; decision support

I. INTRODUCTION

In terms of rapid growth of air transport traffic and propagation of reactionary flight delays, it is essential to perform efficient management of airport facilities, maintaining costs as low as possible and keeping airport's KPIs on the required level. One of the most important problems that airport and airline managers have to be concerned about is efficiency of stand scheduling. Boost of air traffic and congestion of airport capacity have significantly increased the service complexity, which is further complicated by changes in the flight schedule on the day of operation. Poor terminal performance caused by inefficient stand scheduling can lead to decreasing of passenger service quality and increasing of turn-round time that can create a propagation of a delay to the successive flights and connected airports. Thus, it is necessary to make an optimal and effective use of terminal facilities, such as stands, to increase airport performance and to mitigate the propagation of negative effects through the air transportation network.

II. PROBLEM STATEMENT

A. Stand Assignment

The problem of stand allocation or stand assignment (further referred as SAP), as well as the similar problem of gate

allocation, has been widely studied over the decades and numerous approaches have been applied to different sets of objectives, constraints and outcomes. SAP is a scheduling problem, which is NP-hard due to real-life quantity of constraints and decision variables. According to the methodology used, the solving approaches can be divided into three categories: exact algorithms, heuristic algorithms and combined algorithms. While the first ones aim to find the best solution from diverse perspectives, the rest are designed to determine a qualitative near-optimal solution in a reasonable computational time [1]. Due to the complex nature of the problem, exact algorithms (e.g. branch-and-bound algorithm) have difficulty in providing optimal solutions within reasonable computational times for large-scale stand assignment problems. Therefore, recent studies mainly focus on developing heuristic algorithms, which do not guarantee optimal solutions, but may provide near-optimal solutions in reasonable computational times. However, if a heuristic algorithm fails to find the solution, it is not possible to determine whenever it is due to the absence of any solution or due to the inability of an algorithm to move from local search region [2]. On the contrary, this work shifts the scope from the generation of better solutions to the assessment of the generated solutions not only from the objective function's value perspective, but also from the perspective of the risk of inconsistency of the generated schedule to the reality of operations.

Being a structural component of a very complex and tightly interconnected system, airports suffer from various types of uncertainties. This unpredictability is a natural part of the air transportation network, as many activities can suffer changes in the very last moment, affected by the weather conditions, governmental regulations, air traffic control and etc.

One of the main consequences of such uncertainty are flight delays and early arrivals. Some flights suffer from delay, originated in previous legs and propagating through the network as reactionary delays. Other flights can be coming to their destinations earlier than expected. Both of these deviations create additional load to the decision-making process. This work

implies instead of predicting exact values of flight delays, estimate the probabilities of having a certain delay level for each flight and use this information for estimating the quality of the stand assignment schedule.

III. METHODOLOGY

We propose a concept of a stand assignment algorithm that deals both with environmental uncertainties and with optimization of facilities' usage. The algorithm consists of two modules. First module estimates probabilities of delays and their level based on the historical data of previous operational periods. The second module generates the assignment schedule, based on the desired technical and operational restrictions for a target flight schedule, and optimizes it with a genetic algorithm component. To calculate the stand occupancy time for each flight, we estimate in-block and off block times based on the target flight schedule and the delay probability, obtained in the first module.

To generate a stand assignment schedule for a specific operational day, the following data is used:

- Target flight schedule for assignment.
- Existing parking facilities and their technical and operational restrictions (compatible with specific aircraft types, individual use by certain airlines or for certain origins/destinations).
- Availability of stands.

Finally, assignment policy specific data, such as taxi time, walking distances for transfer passengers, etc., are added to the data set as well.

A. Algorithm Architecture

As it has been mentioned in the previous section, the algorithm consists of two modules: one - to estimate the probabilities of delay, and one - to generate a stand assignment schedule, optimized for specific management goal (minimizing transfer passengers walking distances, minimizing taxi time, etc.).

The first module is directly connected to a performance database, which allows re-estimating the delay probabilities in real time, considering also recently available information, e.g. about flight regulations and weather conditions. In this module, the historical delay values are analyzed for different combinations of factors (e.g. airline, aircraft type, operational hour, and weather conditions) and corresponding Bayesian distributional regression models are built. These models together with the corresponding parameters are then passed on to the second module.

In the second module, the target flight schedule is recalculated, according to the regression models obtained in the previous step, and the estimated delay values are added to the block occupancy times. After that, this recalculated flight schedule is passed to a metaheuristic solution search algorithm, which looks for a better stand assignment for the flights, optimizing the user-specified objective function or the weighted combination of them.

The number of iterations, total running time and objective function value can limit the calculation time, according to the user needs. Therefore, the solution quality improvement is only restricted by the user estimations.

B. Algorithm Output

On the exit of the second module component, metaheuristic search algorithm, the stand assignment schedule is obtained. Within the obtained schedule, for every flight, assigned to the stand, the deviation risk value is displayed. This risk value indicates that although the flight is assigned to the specific stand, there is a probability of N percent that this flight will suffer delays and affect the rest of the assignment schedule. By displaying such information, we intend to provide the airport managers with an insight to the most critical points in the schedule and facilitate the decision-making process with a quantitative estimation of possible operational scenarios. In such a way, it is possible to measure the impact of any air traffic regulations on the slot adherence and generate various stand assignment schedules for different performance scenarios with different levels of risk.

IV. CONCLUSIONS

In this work, we present a conceptual solution to the most common airport problem – efficient stand assignment. The presented algorithm combines benefits of data-mining tools and metaheuristic approaches and generates qualitative solutions, conscious to historical delay trends and performance drops. This two-module algorithm generates promising solutions from the first iterations, it provides airport stakeholders with an approach for delay-aware stand assignment and facilitates the estimation of impact of operational disruptions on the slot adherence.

ACKNOWLEDGMENT

Opinions expressed in this paper reflect the authors' views only.

REFERENCES

- [1] J. Guépet, R. Acuna-Agost, O. Briant, and J. P. Gayon, "Exact and heuristic approaches to the airport stand allocation problem," *Eur. J. Oper. Res.*, vol. 246, pp. 597–608, 2015.
- [2] J. Pearl, "Heuristics: Intelligent Search Strategies for Computer Problem Solving," *Telemat. Informatics*, vol. 3, no. 4, p. 305, Jan. 1986.

Technical Exhibit and Demonstration of DataBeacon: The Secure AI Multi-Sided Platform for Aviation

Samuel Cristobal, Jorge Martín
Innaxis Research and Foundation
Madrid, Spain
sc@innaxis.org* jm@innaxis.org

Jens Krüger
Fraunhofer Institute for Industrial Mathematics
Kaiserslautern, Germany
jens.krueger@itwm.fraunhofer.de

Abstract— DataBeacon is a multi-sided data platform (MSP) for aviation data. It encourages the collaboration of aviation stakeholders, research institutions and industry interest and facilitates their exchange of information, thereby enabling value creation for all participants.

big data, multi-sided platform, machine learning and artificial intelligence platform, data availability.

I. INTRODUCTION AND MOTIVATION

DataBeacon is a multi-sided platform¹ that stores aviation data from data owners safely, enables external data analysts to get insights from authorized data and returns results from the analysis to the data owners.

Both roles benefit: data owners get more value from the data they provide and data analysts get data access of high quality datasets to test their algorithms.

The platform has been developed and managed by Innaxis, the Fraunhofer Institute for Industrial Mathematics and Tadorea. The development team of DataBeacon has participated in several research projects within the European Union. Its relevant experience in acquiring, cleaning, merging and maintaining different data aviation sources ensures the high quality of the available datasets and enables the seamless communication between the data owners and the data analysts.

A. features

Aviation datasets **ready to use** for data analysts: as soon as new data comes into the platform, a data pipeline is engaged to improve the quality of the datasets by cleaning the data and merging it with different sources.

Anonymized data. Aviation datasets are anonymized as soon as new data comes into the platform in order to hide crew or passenger identities along with private business details.

Flexible deployment. Two solutions for data acquisition, either by setting up a private cloud environment or by deploying a processing node inside the network of the data owner. This sort of hybrid deployment fits companies that are concerned with the future use of its data.

Availability. The cloud infrastructure is fault tolerant, meaning that as soon as one node of the infrastructure is down, it is restarted and set up automatically. Data storage is distributed among several nodes to reduce the possibility of data loss.

Scalability. Each data analyst who joins the platform will have access to a dedicated cluster to carry their analytics. The data analyst will have a dashboard to check the performance of the cluster and scale up if necessary using a simple web interface. Also the infrastructure itself can be extended by any means as well as each cluster can be extended to increase performance and capacity.

Security. Storage and data preparation clusters are isolated from each other and linked with a dedicated cluster broker in order to ensure data is shared to the right nodes and automatically deleted if a data owner leaves the infrastructure. All elements of the infrastructure need to authenticate themselves. Data in rest and in motion is encrypted.

II. ARCHITECTURE

DataBeacon is built around confidential data sharing from aviation stakeholders and advanced data analytics applied to the shared data.

In order to address the data protection and analysis requirements, the DataBeacon architecture enables the following data analysis paradigms:

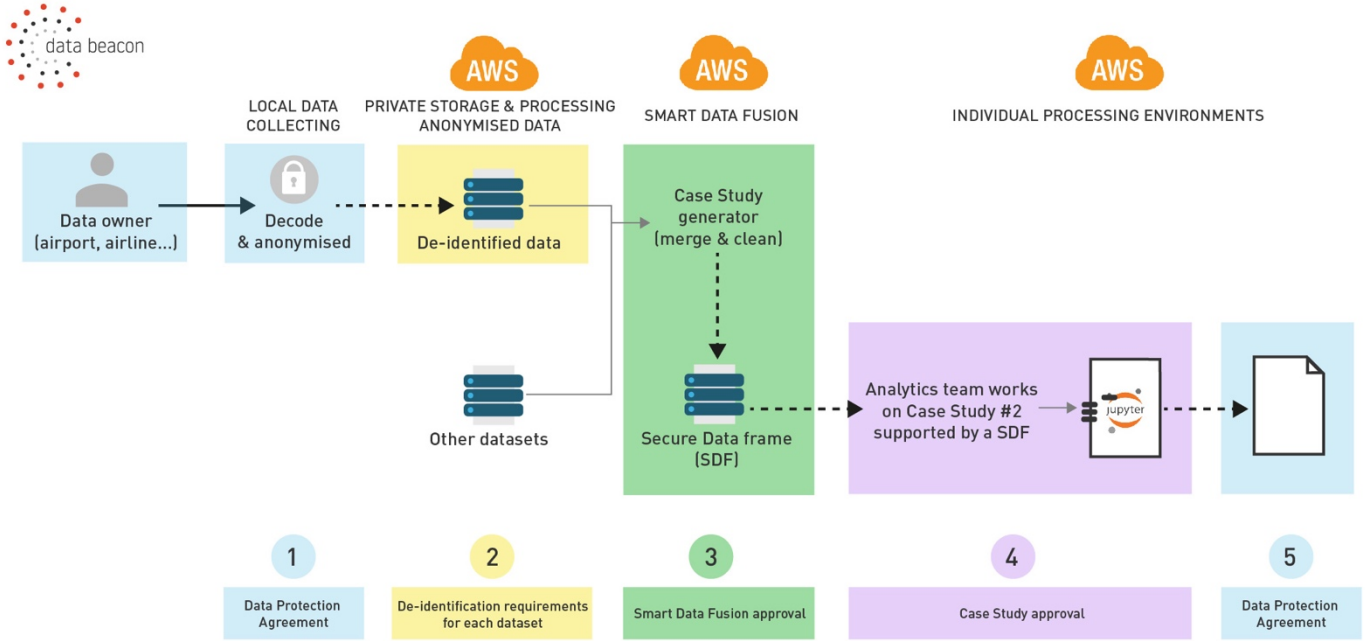
- Fusion of de-identified datasets into Secure Data Frames (SDF)
- Accessibility to the de-identified datasets for data analyses.
- Information sharing based on the analysis of restricted and confidential data among aviation stakeholders
- Data access logging and limitations, data access is continuously monitored.

A. Local Node

The Local Node sits at the premises of the participating companies (e.g. airlines and ANSPs) and stores raw datasets

¹ <https://sloanreview.mit.edu/article/strategic-decisions-for-multisided-platforms/>

from the different source systems. The dataset is de-identified and copied to the DataBeacon private cloud environment. Authorized third parties are allowed access only for data management and administrative tasks; no third-party analysts have access.



D. Public Cloud Environments

The Public Cloud Environments are physically identical to the PCEs but only hold open datasets like Meteo, ADS-B, SWIM, Radar, etc. Access to the data is not restricted in any way.

E. Dataset Broker

Figure 1. The DataBeacon Architecture

B. Dedicated Private Cloud Environments (PCE)

Each participating data provider has a private segment of a cloud infrastructure that is logically and physically independent. It is used for de-identified data storage and analytics. Data scientist of DataBeacon partners will have access to the de-identified data under the data protection agreements. The private cloud environments provide datasets to be merged and shared with the case study environments.

C. Case Study Environments (CSE)

Case Study Environments (CSE) are special environments used to merge datasets from different private environments and to provide this data to the different data analyst teams. A CSE is specific to a use case scenario, e.g., there is a specific environment for unstable approach analysis. On top of such CSEs, is it possible to associate a Sandbox environment for each data analyst team. Each sandbox only has read access to the merged dataset. This way, each analyst team can access the dataset but cannot modify it - the integrity of the data is preserved.

The Dataset Broker decouples the PCEs from the CSEs in a way that handles data merging and other requests. This way, the DataBeacon infrastructure can be extended by any environment type at any time. It also authenticates data requests and serves as buffer in case of unbalanced data bandwidth speeds

III. THE TECHNICAL DEMONSTRATION

The DataBeacon technical demonstration at the SIDs will consist on a series of practical examples showcases and peers-chats oriented for both, users and analysts. There would be a poster showing the functionalities and benefits of the platform, according to the above description.

A team of data scientist and data engineers would be available to answer questions and chat about the platform with the interested audience. Scheduled small talks will be conducted to show the audience the capabilities of the platform through prepared examples, executed in real time. Using either Jupyter Notebooks for analysts of Tableau interactive dashboards for users.

If time allows, there would be a video presentation available. Showing the capabilities and experience of current DataBeacon small ecosystem of users.

Deep Reinforcement Learning for Multiple Drones

Air Traffic Management

Ender Çetin, Guillem Muñoz, Enrique Pastor, Cristina Barrado
Castelldefels School of Telecommunications and Aerospace Engineering
Universitat Politècnica de Catalunya, BarcelonaTECH
Barcelona, Spain

Abstract—Unmanned aerial vehicles, specifically drones, have been used as surveillance, filming and journalism, shipping and delivery, disaster management, rescue operations and healthcare, archeological surveys, geographic mapping, agriculture, wildlife monitoring, weather forecasting etc. Recently the drones are available at low prices but equipped with a high-resolution camera, gyroscope, GPS, flight control unit and different types of sensors. However, the high numbers of drones in the airspace worldwide require an unmanned traffic management system and highly automated drones. In this research, a full autonomous quadcopter drone concept based on deep reinforcement learning (DRL) is presented. AirSim flight simulator is used to train and control the drones. The training can take up to 4 days depending on the training steps and the hardware used. In the simulator, Multi-drones and drone port service will be used, and drones will try to reach the specified destinations inside the area called drone port.

Keywords- Artificial Intelligence; Deep Reinforcement Learning; UAV; Drones; Flight Simulation.

The demand for drone services is steadily increasing, with the potential to generate significant economic growth and societal benefits, as recognized in the 2015 EU Aviation Strategy, and more recently in the 2016 SESAR Drones Outlook Study [1]. In Europe, U-Space defines a set of services for drones flying at the very low level (VLL) to ensure the safety of all airspace users operating in the U-space framework, as well as people on the ground. According to European ATM master plan drone roadmap [2], the skies by 2035 will be at least ten times busier today and the majority of them will be the drones operating beyond line of sight (BVLOS) in all environments using a large variety of services: Tracking, e-identification, emergency management, tactical-geofencing, etc. In addition to these services, in this research we will extend the concept by adding drone port services to manage take-off and landing of drones.

The control of drones operated by human is limited compared to the autonomous operations of the drone. For this reason, in the future, the control of drones is expected to be autonomous to be able to manage the high number of air traffic conflicts and to detect the dynamic obstacles on which drone can crash when flying in the VLL airspace. In this research, we study the capabilities of a fully autonomous drone based on deep reinforcement learning (DRL). This is an Artificial intelligence field where agents learn how to achieve a certain goal from

interaction and has successfully used to train and control the drone. In a study using DRL, the Google DeepMind team demonstrates the efficacy of DRL by training agents to play Atari 2600 games at super-human level. Given sufficient training the agent was able to surpass the performance of all previous algorithms and achieve a level comparable to that of a professional human across a set of 49 games [3].

In DRL the most important components are the *agent*, which is basically the learner and decision-maker, and the conditions or surroundings with whom the *agent* interacts, formerly called, the *environment*. Fig. 1 shows the basic elements of DRL: the agent (the drone), the environment (the airspace) and the interactions between both. Hereby, the agent gets the screen content as state and the change in score as reward. This interaction is carried during a sequence of discrete time steps t .

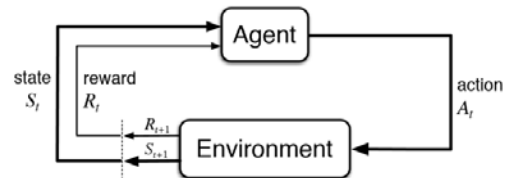


Figure 1. The agent-environment interaction

The agent is a quad-copter drone able to execute 6 actions. Fig. 2 shows the movements of the drone within the environment. The general action is the modification of the velocity on a selected axis x , y or z the equivalent of ± 0.5 m/s but always facing forward, computing the appropriate yaw angle rotation to perform according to the modified velocity. The drone can select one of the six different variations at each time-step.

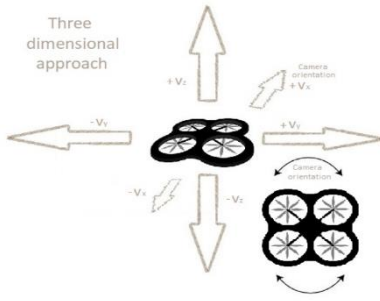


Figure 2. UAV movements within the environment

The environment is the realistic flight simulator called “AirSim” [4] which is used to train and control the drone in a geofenced region inside a suburb environment. The training is full autonomous, and it can take up to 3 or 4 days for 125,000 steps or 250,000 steps respectively on a desktop with Intel Core i7-3770 CPU @ 3,40 GHz and 15,6 GB memory and NVIDIA GeForce GTX 1060.

In this research, multi agent system including multi-drones and drone port service will be used, and drones will try to reach the specified destinations inside the area called drone port. However, in this demonstration 2 drones will be used in AirSim. The drones will avoid moving obstacles in form of other drones. To reach the parking spots, drones can communicate with each other in terms of rewards as change in score and with a drone port service, interchanging messages about the parking numbers and the locations. The drones have to be able to act autonomously to make clear landing and reach the destinations as fast as possible but without collisions. The environment has also static obstacles such as trees, electric cables, houses etc. and drones should learn not to collide with any obstacle and with each other.

In AirSim simulator there are many scenarios available and some of them includes moving obstacles such as cars, pedestrians in addition to drones. In the future, the PhD study will cover the scenery that includes the drones flying inside the environment, moving obstacles, pedestrians and animals. Also, the drone port service will operate as an agent inside the environment to automate the take-off and landing of all of the drones operating. The training of drones will be done considering all moving objects inside the environment, and multiple drones will be trained at the same time.

ACKNOWLEDGMENT

This work has been funded partially by the Ministry of Economy and Enterprise of Spain under contract TRA2016-77012-R.

REFERENCES

- [1] SESAR Drone Outlook Study (2016).
- [2] European ATM Master Plan: Roadmap for the safe integration of drones Into all classes of airspace
Retrieved from <https://www.sesarju.eu/node/2993>.

- [3] Volodymyr M., Koray K., David S., Andrei A R., Joel V., Marc G B., Alex G.s, Martin R., Andreas K F., Georg O., et al. Human-level control through deep reinforcement learning. *Nature*, 518(7540):529–533, 2015.
- [4] Shital Shah, Debadepta Dey, Chris Lovett, and Ashish Kapoor. Airsim: Highfidelity visual and physical simulation for autonomous vehicles. *arXiv preprint arXiv:1705.05065*, 2017.

EMPHASIS (EMPowering Heterogeneous Aviation through cellular SignalS)

Project Overview

Petr Cášek

Honeywell Aerospace
Brno, Czech Republic

Thilo Fath

Airbus Defence and Space
Taufkirchen, Germany

Elena Simona Lohan

Tampere University of Technology
Tampere, Finland

Martin Růžička

Evektor
Kunovice, Czech Republic

Abstract— The key objective of the project EMPHASIS (EMPowering Heterogeneous Aviation through cellular SignalS) is to increase safety, reliability and interoperability of General Aviation/Rotorcrafts (GA/R) operations both with commercial aviation and with emerging drones operations. These aspects are critical elements to secure and improve airspace access for GA/R users in future airspace environments while also improving the operational safety of their operations.

Keywords - *Communication; Navigation; Surveillance; General Aviation; Low altitude operations; Mobile network*

I. INTRODUCTION

The EMPHASIS (EMPowering Heterogeneous Aviation through cellular SignalS) research project aims to increase safety and reliability of General Aviation/Rotorcraft (GA/R) operations at low altitude as well as their interoperability with other airspace users. We plan to achieve this through affordable Communication, Navigation and Surveillance (CNS) capabilities benefiting, among others, from existing and future mobile radio frequency (RF) network infrastructure.

The poster primarily summarizes the outcomes of the concept definition phase of the project and indicates the ongoing and planned activities up to the final project demonstration.

II. PROJECT SCOPE

Although the applicability and benefits of technological research conducted within the EMPHASIS project is expected to be broader, there are three main use cases driving the envisaged research activities [1]:

- GA/R aircraft flying in airspace G are facing the risk of mid-air collisions among GA aircraft and in the future also with unmanned aircraft.

- Rotorcraft flying below 500ft are typically facing challenges with regard to possible degradation of satellite based navigation systems (GNSS) as well as with regard to potential conflicts with emerging drones' operations (U-space) [2].

- GA/R aircraft flying in terminal area are facing the risk of mid-air collisions with commercial aviation.

Considering these use cases, research activities are not restricted to on-board CNS capabilities only, but also take into account possible ways how to complement them with flight supporting services.

III. METHODOLOGIE

The EMPHASIS project started with a state-of-the-art review of wireless channel models and data link solutions (i.e., transmitter-channel-receiver chain) in today's aviation environment, with particular focus on low-altitude aerial vehicles while also taking into account other aviation systems potentially relevant for the considered airspace part [3]. Based on these investigations, recommendations and potential technical solutions for low-cost data links supporting general aviation and rotorcraft operations are proposed and will be further explored throughout the project.

In addition, both air-to-ground and ground-to-air radio propagation channels are investigated with special focus on RF network-based positioning technologies to analyze their suitability for aeronautical vehicle positioning and tracking, respectively [4]. This analysis is the starting point for developing a concept of using radio network-based positioning techniques in aeronautical applications in order to improve the operational safety of their operations by enhancing the reliability and consistency of positioning and navigation algorithms.

In the surveillance area, the project focuses on the development of affordable cooperative surveillance schemes addressing interoperability needs both between GA and commercial aviation as well as between GA and other low altitude airspace users such as gliders, balloons, or drones [5].

As affordability is obviously an important aspect to be considered when addressing general aviation users, the project also explores possible ways of alternative certification means for the developed systems taking into account operational specificities and risks associated with low altitude operations.

ACKNOWLEDGMENT

This project has received funding from the SESAR Joint Undertaking¹ under the European Union's Horizon 2020 research and innovation programme under grant agreement No 783198, which is gratefully acknowledged. The opinions expressed herein reflect the authors' view only. Under no circumstances shall the SESAR JU be responsible for any use that may be made of the information contained herein.

REFERENCES

- [1] EMPHASIS D2.1, EMPHASIS Initial Concept, August 2018.
- [2] CORUS Concept of Operations for U-space, SESAR 2020 RPAS Exploratory Research, Eurocontrol, June 2018.
- [3] EMPHASIS D4.1, Open challenges in wireless communication network usage for low-cost data links and flight support services for GA/R, September 2018.
- [4] EMPHASIS D5.1, Radio channels and their use for General Aviation / Rotorcrafts (GA/R) positioning, October 2018.
- [5] EUROCONTROL, General Aviation Surveillance - Concept of Operations, EUROCONTROL Surveillance Modernisation Support Group, 2017.

Building a Safe and Socially Acceptable Concept of Operation for Drones Flying at Very Low Level

Cristina Barrado, Enric Pastor
Universitat Politècnica de Catalunya
Castelldefels, Spain
Contact: cristina.barrado@upc.edu

Keywords – *conops, drones, U-space, unmanned traffic management, public acceptance*

As part of the Single European Sky ATM Research (SESAR) a number of projects related to the drones flying at the very low level (VLL) have been funded. At its core, the CORUS project is developing the concept of operations (ConOps) of these drones¹. At the same time, the last European ATM Masterplan has proposed the “Roadmap for the safe integration of drones into all classes of airspace”². This document proposes the set of services for the unmanned air traffic management, named as U-space, together with a calendar for their deployment (from U1 to U4). The CORUS project integrates these services as pillars of the ConOps, with the objective of supporting the new businesses and jobs, improving the safety of the drones, and dealing with their public acceptance.

From the airspace perspective, the main problem of drones flying at the very low level (VLL) is that, although mostly empty, the VLL airspace is shared with other airspace users: military, general aviation, parachutes, gliders, emergencies, take-off and landings, high-precision aerial works, training, etc. Most of the drones are today flying in visual line of sight (VLOS) operations, where the remote pilot can see the aircraft and separate from nearby traffic. On the contrary, beyond visual line of sight (BVLOS) operations, where the pilot cannot directly see the drone, relatively rare today, are expected to be the normal way of operating for many future commercial drone activities. The expectation for 2035 is airspace ten times busier than today due to additional business models related to drones, which involve a large amount of turnover, capital investment, and jobs creation, direct and indirect. Very diverse economic areas such as agriculture, energy, transport, construction, inspection, delivery, security, insurance, commercial, but also arts or leisure, are expected to benefit from the use of drones in the very near future.³

As with previous emerging technologies, the social aspects of the risk acceptability include voluntary involvement, the

nature of the consequences of failures and transparency⁴. Transparency and inclusiveness are the two most common principles that foster acceptance: Transparency means that information shall be transmitted in an accurate and timely way, using common and understandable language, and shall be verifiable. Inclusiveness means that the affected individuals and social associations shall be empowered to influence the decision-making process⁵. The impact of drones on privacy is also relevant for their acceptance⁶. The obligations to respect privacy for drone operators include the transparency principle again, the proportional principle (by using the proportional technology to avoid collecting unnecessary data), and the purpose limitation principle (to avoid any secondary use of the data without permission)⁷. Similarly, the obligations extend to the necessity to adopt security measures and to embed privacy-friendly procedures in the design of the operations⁸. Two more aspects influence the perception of drones: the capability of law enforcement agents to mitigate and/or punish those responsible for wrong-doings, and the noise⁹.

The CORUS ConOps tries to balance the economic growth, the safety and social acceptance. Its current status contains two main issues: a classification of the VLL airspace, and a first U-space services refinement, with special attention to strategical services. CORUS proposes to classify the VLL airspace using a three colours scheme. The colour scheme is inspired by the traffic lights to be easy to understand by all (transparency principle): red for prohibition, amber for alert and green for free access. Colours do not segregate traffic; rather they provide information about the different performance

⁴ Gupta N. et al., “Socio-psychological determinants of public acceptance of technologies: A review”, Public Understanding of Sciences, Vol 21(7). SAGE Journals 2011.

⁵ European Grid Declaration. “Grid infrastructure communication toolkit”. <https://webgate.ec.europa.eu/multisite/gridcommunicationtoolkit/>

⁶ Working Party on Article 29 Data Protection, “Opinion 01/2015 on Privacy and Data Protection Issues relating to the Utilisation of Drones”, EC 01673/15/EN - WP 231, June 2015.

⁷ ULTRA Consortium, “Unmanned Aerial Systems in European Airspace”, FP7 Project. EU Available at <http://ultraconsortium.eu/>, 2014

⁸ Reece A. et al., “Risk Perception And The Public Acceptance Of Drones” Risk Analysis Volume 35, Issue 6, Feb 2015.

⁹ Lidynia C. et al., “Droning on about drones—acceptance of and perceived barriers to drones in civil usage contexts”, Advances in Intelligent Systems and Computing 499, 2017.

¹ CORUS ConOps V1.0 <https://www.eurocontrol.int/sites/default/files/publication/files/corus-concept-of-operations-1.0.pdf>

² SESAR JU, “Roadmap for the safe integration of drones into all classes of airspace”. March 2018.

³ SESAR JU, “European Drones outlook study, unlocking the value for Europe”. November 2016.

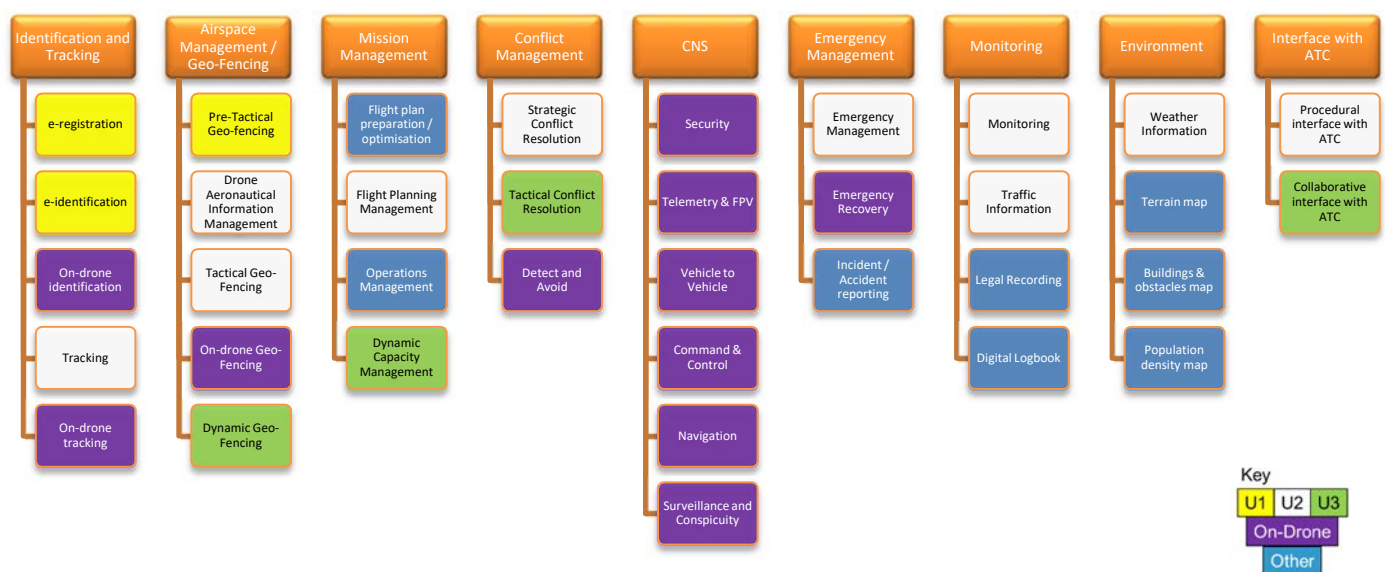
requirements and U-space services being offered. National authorities will be responsible for defining the VLL airspace colour distribution within their airspace.

The red airspace can be imagined of as a no-flight-zone area. Reasons for red airspace are related to social acceptance issues, such as environmental preservation, citizens' low noise areas and for privacy or security reasons — for instance, the airspace above a National park, the area close to a hospital or the surrounding of a nuclear power station. However, red airspace might still permit the flight of very controlled and limited drone operations — for instance, an urgent delivery in a hospital, or the surveillance of a natural area for its protection.

The green airspace will be, on the contrary, open to any drone, including citizens' leisure drones. Green airspace will exist where the risk and annoyance associated with the drone operation are low, generally over non-populated areas. For the time being, only VLOS operation are foreseen in the green

airspace. Moreover, few U-space services will be offered, basically the foundation services and the emergency service. For social acceptance, the E-identification service is considered to be crucial. Finally, due to safety, the geo-fencing and the emergency services will be available, which could also be used by other VLL airspace users.

Halfway, the amber airspace defines an area of the VLL airspace able to support safe BVLOS operations and foster most emerging drone business. These are operations declared as Specific by EASA, because of their medium risk level. VLOS operations can be declared as Specific if the mass or the speed of the drone is above some given thresholds. For those operations, the legal requirements are more stringent, and the provision of the U-space services will add the necessary safety without reducing airspace capacity. For instance, tracking will be a necessary service to foster a shared use of amber airspace.



The full set of U-space services is shown in the figure as coloured by their deployment phase and grouped by functionality. Moreover, new proposed services (in blue) and on-drone capabilities (in purple) have been added. For instance, three new services related to *Environment* have been included. One of them related to social acceptance, *Population density*, can help operators to find noiseless routes. Highly relevant to the tactical phase are the *Identification and tracking* services. *Tracking* collects unique position reports of the flying drones and triggers some other added value services such as monitoring, conflict and emergency management. For instance, accident and incident investigation will require that position reports to be logged securely for some period. The *Geo-fencing services* extend the basic airspace information service by exploiting the self-separation capability of the drones. The *Mission management* services shall allow the drone operators to express their operations with high flexibility: from “in this

volume during that period” for a survey flight, to a precise description of the full path for a delivery drone.

There is still a lot of work to carry out to develop the final version of this ConOps. The consortium will work intensively over the next few months aiming to produce its version 2 by March 2019. The CORUS team is interested to hear your comments. Feel free to send them to our email: corus-info@eurocontrol.int.

ACKNOWLEDGEMENTS

This work has been prepared by all CORUS partners: DLR, DFS, DSNA, ENAV, EUROCONTROL, HEMAV, NATS, Unifly and UPC. The list of authors would be too long to include them all, but we would like to acknowledge them now.

This work has been partially funded by the SESAR Joint Undertaking, a body of the European Commission, under grant H2020 RIA-763551.

The Resilient Properties of Multiple Remote Tower Operations: LFV RE5

Anthony Smoker
Lund University School of Aviation,
Lund University
Ljunghed, Sweden

Jonas Lundberg
Media and Information Technology
Department of Science and Technology
Linköping University
Norrköping, Sweden

Billy Josefsson
LFV Air Navigation Services of Sweden
Norrköping, Sweden
billy.josefsson@lfv.se

Rogier Woltjier
Swedish Defence Research Agency
Stockholm, Sweden

Abstract—A resilience engineering assessment of the resilient and adaptive capacity of a Remote Tower Centre was undertaken. It was concluded that changes to the works system led to new sources of resilience and adaptive capacity.

Keywords: *Resilience Engineering, Multiple Remote Towers, Adaptive Capacity, Service Provision, Analysis of work systems*

I. INTRODUCTION

Multiple remote tower operations are envisaged to be an operational evolution of the future Air Traffic Management (ATM) system. Single-Mode-of-operation remote towers have been deployed and are operational. The pace of deployment of single-mode-of-operation remote towers is set to increase. Multiple Remote Tower Operations holds the potential of operating and service provision efficiencies [1].

A study of the resilient properties of a hypothesised Multiple Remote Tower (MRTWR) Work system as a Remote Tower Centre was undertaken to explore operational capabilities to adapt and sustain an ATS service. A resilience engineering assessment method developed by SESAR [2] was used.

The RE5 research project aims to:

- Understand the ability of an RE5 Multiple-Remote Tower-Mode-of-operation ATS facility to handle variations in everyday operations
- To explore the strategies that are used to respond and handle variations and the nature of adaptive capacity of the work system
- Review and explore the concept of Remote Tower Centre in terms of resilient performance

II. REMOTE TOWER CENTRES

A. Remote Tower Centre Operating Modes

Single-mode-of-operation remote towers are discrete units of ATS operation that are self-contained at a remote location.

Multiple-Mode-of-operation differs in the ability to provide air traffic services at multiple airfields remotely in a single controller working position e.g. a Remote Tower Module (RTM). Several Remote Tower Modules can be co-located at one location.

The number of remote towers that can be operated from one RTM is assumed to be three representing the current belief.

Multiple-mode-of-operation requires a different social organisation of the work system to accommodate the task load constraints of multiple tower ATS provision from a single Remote Tower Module. The RTM ATCO providing ATS at 2 or 3 airfields simultaneously is limited in the extent of the tasks that can be undertaken concurrently, including coordination and communication tasks. The nature of work-as-imagined/done [3] is thus different from single-mode-of-operation.

RE5 assumes multiple-mode-of-operation ATS provision for five airfields of varying density of traffic and disparate traffic characteristics that are combined into one Remote Tower Centre. The airfields selected for the study were: Malmö, Umeö, Kiruna, Ostersund and Örnsköldsvik.

Current EASA Acceptable Means of Compliance and Guidance material for remote towers makes provision for a supervisor as optional [4]. A number of assumptions were made about the social organisation of a RE 5 RTC and then further developed, with knowledge elicited from participants in the research project.

The RE5 Remote Tower Centre operates as a managed operation with the establishment of a supervisory role. This leads to a different social organisation within the RTC. This allows for different RTC operational configurations of the three remote tower modules and five remote tower operations.

B. Method

The SESAR SRM Resilience Engineering Assessment method takes a systemic approach to understanding a socio-

technical system or work system in the current operation as well as assessing the envisaged work system design of the future.

The principal data collection tool is a workshop with practitioners experienced in the current operation, well versed and conversant with the envisaged operation and the future concept of operation.

The workshop elicits a picture of the operational landscape, both current and future, to build a system view of the work system. The emphasis is on work as done and other archetypes of work for a typical operational day.

Operational challenges and variations experienced in a typical operation are elicited using a knowledge elicitation approach. Beginning with a description of the work system, to derive system actors and artefacts, this is then used to understand interactions and dependencies within the work system itself.

The next step is to develop an understanding of the nature of the varying conditions and challenges that are encountered in a typical day's operations and to then elicit the strategies used to manage these, for both current and envisaged operations

Workshop data is subsequently coded using a Resilience Engineering coding frame that considers seventeen aspects of adaptive strategies, the sources of resilience drawn upon and exploring the coordination costs and consequences of the strategy for defined actors in the work system.

Work system resilience is investigated using the Systemic Resilience model [4] and visualisations of the work system that are derived following the style multi-actor representations, [5], visualisations of the flow of tasks [6] and analysis of adaptive capacity [6] depicted in Figure 3.

III. FINDINGS

If two or more towers are combined into one multiple-mode-of-operation RTM there is an increase in task load, notably competing coordination and communication, which need scheduling or prioritising. The sum effect is that there is a need to manage the situation using strategies to cope with the competing demands from each discrete airfield. These strategies were elicited forming the basis to examine a managed MRTWR RTC. As a result, new sources of resilience and ways to adapt were found.

The organisation of an RE5 RTC differs in that the scale of the operational work system with new actors and artefacts. This was found to hold the potential for new sources of resilience that expand the *capacity for manoeuvre* and introduces new ways to configure the operational environment. This new ability to adapt could be gained through the interfaces and interactions with adjacent ATSUs as well as from intrinsic RTC properties. For example, the availability of additional ATCO resource to support tactical strategies that separate multiple-mode-of-operation into two single-mode-of-operation. This requires new operational decision making, that exploits the adaptive capacity of the work system.

This approach, the operational managing of a Remote Tower Centre, provides ways that optimises the available capacity for predicted traffic demand and that sustains service delivery effectively.

To fully exploit the potential new sources of resilience of a Remote Tower Centre, new requirements for tools and methods of working were found.

The timeliness and availability of sources of resilience is a facet that the research explored,. Coordination and communications tasks were found to have new dependencies and consequences for adjacent actors

Adaptive capacity expands in an RE5 RTC because of the ability to reconfigure the RTMs and the allocation of remote towers to RTC configurations that optimise demand and capacity and the use of traffic management tools to ensure timely reconfiguration .

To realise the potential of a resilient RTC the ability to access the sources of resilience in an RE5 RTC requires new capabilities that support timely recognition of the need to reconfigure RTMs and be able to do so effectively.

IV. CONCLUSION

Remote tower operations in multiple mode of operation managed in an RTV holds the potential for new sources of resilience and a scope and capacity to adapt that offers new ways to sustain operations. This can be achieved through operational decision making that exploits a new social organisation.

ACKNOWLEDGMENT

This study was funded by the Swedish Transport Administration and the LFV Air Navigation Services of Sweden through the Automation programme in cooperation with Linköping University.

REFERENCES

- [1] Saab Digital. Our Solutions. <https://saab.com/security/air-traffic-management/digital-air-traffic-solutions/solutions/> Accessed 2018/09/10.
- [2] SESAR P16.06.01, D26 - *Guidance to Apply the SESAR Safety Reference Material*, Edition 00.02.01, 9th March 2015
- [3] I.K. Moppett and S.T. Shorrock, "Working out wrong side blocks". *Anaesthesia*. vol. 74, pp. 407–420, December 2017
- [4] EASA. "NPA 2017: *Guidelines on Remote Aerodrome Air Traffic Services*". EASA Cologne
- [5] Lundberg, J and Johanneson., "Systemic resilience model". *Reliability Engineering and System Safety*., Vol 141., pp. 22-32, 2015
- [6] Branlat, M., "*Challenges to Adversarial Interplay Under High Uncertainty: Staged-World Study of a Cyber Security Event*". Phd Thesis Ohio State University, 2011. <https://etd.ohiolink.edu/>
- [7] Lundberg, J and Woltjer, R. The Resilience Analysis Matrix (RAM): visualising functional dependencies in complex socio-technical systems". Proceedings of the 5th Resilience Engineering Association Symposium, Soesterberg, July 2013

An Empiric Stress Test Validation for Multi Remote Tower Safety Assessment

Lothar Meyer, Billy Josefsson, Maximilian Peukert

Research and Innovation
LFV Air Navigation Services of Sweden
Norrköping, Sweden

{lothar.meyer} {billy.josefsson} {maximilian.peukert}@lfv.se

Jonas Lundberg

Department of Science and Technology
Linköping University
Norrköping, Sweden
jonas.lundberg@liu.se

I. INTRODUCTION

Current LFV research activities focus on the foreseen approval process of a Multi Remote Tower-Concept of Operations. The concept base on the assumption that tower controllers are capable to provide tower control services at two airports with low traffic density at a time while workload turns out well- balanced. Especially the workload and the distribution of attention of the tower controller was subject of several research activities and regarded as critical when controlling two airports [1][2][3]. In the scope of the approval process, three safety workshops were carried out in 2016 and 2017 with three LFV tower controllers and one pilot. The output was a list of identified multi remote tower-specific hazards in which the human error type confusion of equipment and information was considered as most harmful. This type of error was confirmed as safety-relevant in a concept study [2].

Methods for the Empiric Risk Assessment of Socio-Technical Systems in ATM (MERASSA) is a concept method that was proofed and validated at the Multi Remote Tower - case with the objective to enrich the safety assessment with empiric data, to evaluate the hazards and to benchmark the level of safety compared to a single airport remote tower [4]. By means of human-in-the-loop simulations, stress test scenarios are used that shall test the correctness and speed of response of the test person when being confronted with a challenging test situation. This allows for a fair comparison and thus a benchmark of the tower controller's capability to act in a multi remote tower in regards to the identified hazards.

This poster presents the method and the first result of the MERASSA validation study.

II. METHOD

The design of the stress test relies on a scenario at Sundsvall and Örnsköldsvik Airport in a 90 minute simulator run. Test procedures are embedded for building up a certain test situation:

- *2 equipment handling tests:* The test person is instructed to release the emergency squawk or set a certain frequency at a certain airport. These tests address the possible confusion of equipment.

- *3 conflict tests:* The test person is confronted with the sudden appearance of obstacles on the runway and a flight path approximation in the CTR between a VFR and IFR movement that the test person is supposed to identify and solve by separating the VFR. These tests address the attention on the Out-the-Window view and radar.
- *6 Situation Present Assessment Method (SPAM):* The test person is asked for operational relevant parameters such as QNH, braking action values, wind speed and position of A/Cs in the CTR. These tests address the possible confusion of operational information.

The primary safety metrics are speed and correctness of response. The test person was instructed to act as fast as possible when a test procedure was applied.

For each trial, 11 tests were applied with each test sampling a reaction time and a success of action. In the case of the conflict test, the recognition of the event marked the completion of the test. The test was cancelled after a maximum period of 3 min. The traffic mix consisted of 2 inbound and 3 outbound IFR movements and 2 VFR as well as 2 flightschools exercising touch and go landings. In the multi scenarios, the amount of traffic movements was shared over 2 airports.

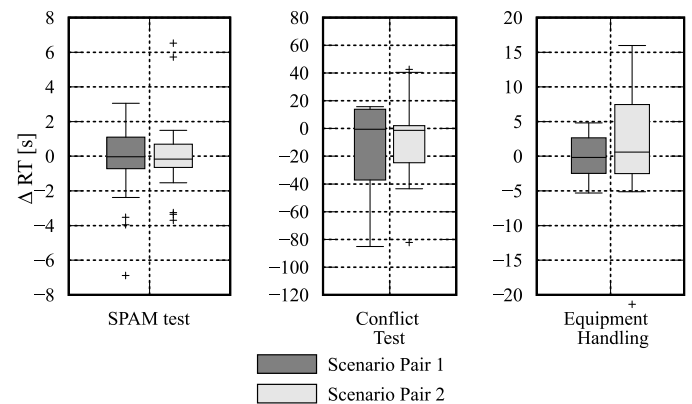


Figure 1. Box plot of test procedures

III. RESULTS

Six LFV tower controllers from RTC Sundsvall, Tower Stockholm-Arlanda and Tower Kristianstad were trained in a 2 days session and passed then each 2 single and 2 multi scenarios. The sequence of trials alternated between single and multi-scenarios as a “crossover” design for counterbalancing confounding factors. Each single scenario is related to a specific multi scenario in terms of timing of the events but with randomized callsigns and A/C models for obscuring the test person. The paired scenarios were defined as Scenario Pair 1 and 2 in which each test is applied under similar conditions.

A. Reaction Times

A total of 238 reaction time samples could be collected and were paired as following:

$$\Delta RT = RT_{\text{multi}} - RT_{\text{single}}$$

The box plot Figure 1 shows the resulting distribution of the three types of tests of the independent scenario pairs 1 and 2. The related statistics are shown in Table 1 including Cohens effect sizes that assume a standard distribution. The SPAM tests show a fairly symmetric variance for both scenario pairs whereas the conflict show rather high response times in single conditions. The response times of equipment handling tests indicate a slower reaction in multi condition for scenario pair 2.

TABLE I. TEST STATISTICS

Test	Scenario Pair	ΔRT n	Mean	SD	Effect Size
SPAM	1	25	-0.1	2.2	0.05
	2	34	0.1	1.9	0.04
Conflict	1	12	-7.1	75.5	0.09
	2	16	-7.3	30.0	0.24
Equipment Handling	1	8	-0.1	3.3	0.01
	2	12	1.2	9.1	0.14

B. Safety Benchmark

The inverse of reaction time is the working speed. Combined with the errors committed during the test, each scenario can be related to a working point on the mean speed vs. accuracy plane. For showing the trade-off between both these metrics, we regard accuracy as the error rate as shown in Figure 2. A linear regression curve shows the specific trade-off between working speed and error rate while intersecting the origin. The linear regression indicates a 142% higher error rate for multi scenario conditions at the same working speed.

IV. CONCLUSION

The results show that working under multi scenario conditions affect the test person in terms of reaction time as well as possible human errors at particular points. Most obviously, the test persons show faster reaction times at the conflict tests in multi scenario conditions. What could be firstly seen as an advantage might be a sign of a compensatory act because the test

person feels uncertain or challenged. In combination with the safety benchmark, the obvious explanation is an accelerated working behavior that becomes most clear at the intensified efforts to find the conflict.

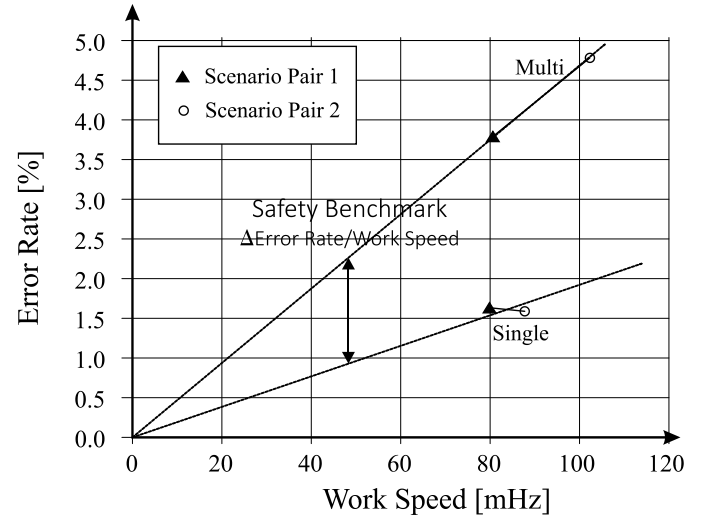


Figure 2. Safety Benchmark

In contrast, the equipment handling tests show slight indications that additional time is needed in multi scenario conditions for identifying the airport. This complies with a specific SPAM test in which the test person was forced to identify the airport of a specific vehicle callsigns which took about 1 sec.

In summary, it is assumed that working under multi scenario conditions is burdened by a test person’s working habit that is well trained and optimized to a single runway layout. The safety benchmark shows most probably the typical outcome of working conceptually out of usual habits. This concerns especially the working methods of managing the attention whose training curve has not converged against a regular pattern. A clear need to develop training methods that help the ATCOs to manage attention can be concluded.

- [1] SESAR JU, “Remotely provided air traffic services for two low density aerodromes appendix F: HP Assessment Report”, Project 6.9.3 D29, Brussels, 2015.
- [2] L. Meyer and H. Fricke, “Investigating the safety-Relevance of limited distinctive features on a multi remote tower-working position.” Proceedings of the 6th Sesar Innovation Days, Delft, 2016.
- [3] A. Papenfuss and M. Friedrich, “Head up only—a design concept to enable multiple remote tower operations.” Digital Avionics Systems Conference (DASC), 2016 IEEE/AIAA 35th. IEEE, Sacramento US, 2016.
- [4] L. Meyer, J. Lundberg, B. Josefsson, L. Danielson and H. Fricke, “Methods for the empiric risk assessment of socio-technical systems in ATM”, Poster Publication on the 5th Sesar Innovation Days, Bologna, 2015.

Advances in ATM Simulation by Using the Global Flight Simulation Framework NAVSIM

Carl-Herbert Rokitansky, Kurt Eschbacher, Martin Mayr, Fritz Zobl
Institute of Computer Sciences / Aerospace Research Department
University of Salzburg
Salzburg, Austria
roki@cosy.sbg.ac.at

Abstract— Since 2002, University of Salzburg, in close cooperation with. Mobile Communications R&D Forschungs GmbH, has developed and continuously enhanced NAVSIM a consistent ATM/ ATC/ CNS/ MET simulation framework. This framework allows to simulate actual and future worldwide air traffic very accurately and is also capable to simulate corresponding aspects of this domain like aeronautical data-link technology's, for example VDL Mode 2, L-DACS and/or Satellite links. NAVSIM has been used in numerous national and international projects for human in-the-loop and system performance evaluations (Eurocontrol, European Space Agency (ESA), SESAR, Austrian Research Promotion Agency (FFG), Aviation Industry, etc.).

Keywords—component; Air traffic simulation, aeronautical communications, ATM/ ATC/ CNS/ MET simulation, NAVSIM

I. INTRODUCTION

NAVSIM is an ATM/ATC/CNS simulation framework and is used to simulate European and world-wide air traffic based on specific reference days in the past (around 36.000 flights within 24 hours for Europe and 110.000 flights worldwide). It can be used as real-time and fast-time simulator depending on the main focus of the simulation project. It allows accurate runway-to-runway and/or gate-to-gate simulation by using various sources of data like real air traffic traces extracted from Eurocontrol/ Network Manager (NM) data, worldwide flight scheduled data, or flight plan data. Thereby, NAVSIM is using worldwide navigation data and considers aircraft performances, SID, Enroute (i.e. airway system, Great Circle, or 4D-trajectory), Arrival (STAR), Approach and Final Approach. NAVSIM may be used for evaluating future digital aeronautical communications, SESAR 4D-trajectory concepts, weather impact on ATM/ATC, wind-optimized routing, ATM performance, advanced Flexible Use of Airspace (aFUA), UAV/ UAS in non-segregated airspace, aircraft noise modelling, remote tower simulation, advanced airport operations and CDM/ SWIM concepts, and future air traffic controller training featuring both voice and CPDLC communications [1].

II. AIR TRAFFIC SIMULATION IMPLEMENTATIONS

Each simulated aircraft has an individual and interactive flight management system (FMS) instance, simultaneous access to several hundred thousand of actual ATM data and is

accurately modelled by its type specific EUROCONTROL/ BADA3 aircraft performance model (APM). Furthermore, NAVSIM achieves a very precise and realistic flight behavior and close-to-real-world ATCO interaction capabilities by providing interactive Virtual-Pilot-Instance (VPI) controlling of the aircraft. It is possible to run simulations in manual or auto ATC mode where a rule-based AI system is controlling and - if configured - optimizing the flightpath of each simulated flight. To enable human in-the-loop integration [2] also various data and voice interfaces are implemented to provide manual ATC to the aircrafts. The simulator also allows to simulate adverse weather conditions, calculate avoidance routes and optimized 4D trajectory based continuous descent approaches.

NAVSIM is capable to simulate worldwide actual and future (up to 2050) air traffic scenarios accurately from any worldwide aerodrome via published Standard Instrument Departure (SID) routes, Enroute phase - within an Air Route Network (ARN) or considering future free route airspace, Standard Arrival Route (STAR), Approach and Final Approach Route to the runway of the destination aerodrome [6]. This air traffic simulation is based either on:

- Real air traffic (IFR flights) in the past for a reference day (e.g. peak day in summer)
- Scheduled flight data in the past or near future for all airline, charter and cargo flights (as far as provided by air carriers)
- Any individually defined air traffic scenario created by state-of-the-art NAVSIM flight plan generator
- Any defined validation exercise scenario
- Recorded air traffic tracks in standard radar-data or multi-lateration format (ASTERIX Cat. 62, 48 and 20)
- Recorded air traffic provided in any user defined data format
- GPS based data from measurement flights.

Based on the above data, future air traffic scenarios (up to 2050) can be predicted, generated and simulated by NAVSIM, considering official air traffic forecast data (e.g. Euro- Control Short-/ Medium-/ Long-term forecasts).

III. INTERFACE AND NETWORK-CONNECTION TO NAVSIM

Since many simulation campaigns require interaction with other systems, devices or humans, NAVSIM is designed to run in parallel to other systems and on spatially separated computer systems. To interact with other systems a network interface for the data exchange has been specified. For simple simulation setups with very few system components NAVSIM exchanges data in JSON format via Web-Sockets, for more complex setups NAVSIM makes use of its SWIM compliant X23 protocol [7].

For the interaction with the ATCO it accepts ATC instructions either as:

- Datalink message – via Controller–Pilot Data Link Communication (CPDLC) messages encoded as specific JavaScript Object Notation (JSON) messages
- ATC voice message – via NAVSIM's high sophisticated automatic speech recognition (ASR) virtual voice-radio module.

It is possible to route aircraft to a specific way point or to use radar vectoring and instruct a new heading. Also speed and flight level changes with different climb/descent rates as well as clearances for ILS approaches and landing can be instructed this way. Each instruction is received and processed by the addressed aircraft via the corresponding Virtual-Pilot-Instance (VPI) which is controlling the aircraft. Aircraft present in the test scenario but not controlled by a human-in-the-loop ATCO [3] like departing aircraft or aircraft outside the ATC sector are controlled by NAVSIM-AI auto-ATC instances.

NAVSIM is capable to calculate an optimized arrival sequence and provides 4D trajectory proposals for arrival routes and calculated time of arrival (CTA) for each individual aircraft. During the simulation process NAVSIM continuously calculates, updates and outputs - as JSON or X23 messages - aircraft position data according to the human and auto ATC input and their execution through the virtual pilot instances.

All flights are identified by a unique ID, via which they can be processed and displayed by external visual systems consistently. To support evaluation and assessment of simulation campaigns, NAVSIM records all in- and outputs and continuously calculates and records various KPIs (Key Performance Indicators) for safety, operational performance and efficiency.

IV. DOMAINS COVERED BY NAVSIM/ USBGSIM

In the context of numerous research projects carried out in the past, the "Aviation Competence Center Salzburg" (ACCS) has been set up. Currently the following domains are available:

- NAVSIM/ Air Traffic Generator: Simulation of the relevant airport-specific, European or world-wide air traffic
- NAVSIM/ Airport with the following working positions: Clearance Delivery (CDC), Apron 1 und Apron 2, Ground, Tower

- USBGSim Support Tools: Generic Flight Strip Tool and Arrival/ Departure Manager (AMAN/ DMAN)
- USBGSim/ Tower / Remote Tower Simulator: Visualization of detailed airport scenarios, see Figure 1
- NAVSIM/ ATC: Air Traffic Control working positions (En-Route ACC Sectors, TMA, etc.)
- Cockpit Simulator (Diamond DA42 certifiable)
- NAVSIM/ Dispatch and Airline Operations: detailed flight planning (inclusive MET; in progress).



Figure 1. Tower / Remote Tower Simulator located in the Aviation Competence Center Salzburg (ACCS) depicting on of the developed and implemented Navsim/ USBGSim domains

ACKNOWLEDGMENT

The research leading to recent results has received funding from the European Union's Horizon 2020 Research and Innovation Programme, Eurocontrol, European Space Agency (ESA), Austrian Research Promotion Agency (FFG)

REFERENCES

- [1] C.H. Rokitansky, M. Ehammer, and T. Gräupl, "Newsky – Novel Simulation Concepts for Future Air Traffic," in Proc. 1st CEAS European Air and Space Conference, 2007, pp. 611-618.
- [2] T. Gräupl, B. Jandl, and C.-H. Rokitansky, "Simple and Efficient Integration of Aeronautical Support Tools for Human-In-the-Loop Evaluations," in Proc. ICNS'12, 2012, pp. F4-1-F4-9.
- [3] T. Gräupl, M. Mayr, and C.-H. Rokitansky, "A Method for SWIM-Compliant Human-in-the-Loop Simulation of Airport Air Traffic Management," in International Journal of Aerospace Engineering. 2016. 10.1155/2016/6806198.
- [4] C.-H. Rokitansky, K. Eschbacher, F. Zobl, W. Kallus, R. Schmidt, "Intelligent Airport Operations and Advanced Arrival Management Algorithms & Decision Support Tools," in Aviation Psychology in Austria 2018, ed. Kallus, W. (in print).
- [5] M. Steinheimer, C. Gonzaga-Lopez, C. Kern, M. Kerschbaum, L. Strauss, K. Eschbacher, M. Mayr, C.-H. Rokitansky, "Air traffic management and weather: the potential of an integrated approach," in INAIR 2016 - International Conference on Air Transport 2016.
- [6] C.H. Rokitansky, M. Ehammer, and Th. Gräupl, "NEWSKY – Building a Simulation Environment for an Integrated Aeronautical Network Architecture," in Proc. 26th DASC, 2007, pp. 4.B.4-1 - 4.B.4-11.
- [7] Gräupl, Thomas & Mayr, Martin & Rokitansky, Carl-Herbert. (2016). A Method for SWIM-Compliant Human-in-the-Loop Simulation of Airport Air Traffic Management. International Journal of Aerospace Engineering. 2016. 10.1155/2016/6806198.

Guidelines and Single-EEG Automated Method for the Assessment of Drowsiness: Validation Results and Method

Christian Berthomier, Marie Brandewinder

Physip
Paris, France

J  r  mie Mattout

INSERM, U1028, UMR 5292
Lyon, France

Jacques Taillard

SANPSY Sleep, Attention & NeuroPSYchiatry
University of Bordeaux, USR CNRS 3413
Bordeaux, France

Abstract — Drowsiness is classically defined as an altered state of physiological wake. EEG is the gold standard for the its evaluation. Scoring rules for visual analysis were proposed, the Objective Sleepiness Scale (OSS) for instance. Our objectives were both to validate a drowsiness measurement algorithm based on a single EEG channel only, and to improve the reliability and facilitate the use of the OSS by proposing guidelines to explicit its visual criteria. Based on the comparison results, we made existing rules more explicit for further studies on drowsiness and on the contribution of drowsiness to operational performances.

Keywords – Drowsiness; EEG; Single Channel; Automated Analysis; Objective Sleepiness Score; Visual Scoring Rules

I. INTRODUCTION

Drowsiness is a multifactor phenomenon, which can be linked to fatigue, time of day (or night), jet lag, sleep deprivation, medical conditions (sleep disorders), drugs ...

Drowsiness is modulated by individual factors; some individuals are very vulnerable to night-time drowsiness while others have the capacity to maintain their alertness [1]. It is classically defined as an altered state of physiological wake, as a propensity to sleep. The definition of drowsiness relies on purely physiological grounds. It is sometimes assessed based on the analysis of peripheral signals only, such as eye activity (blinks or pupillometry [2][3] or heart activity [4].

However, EEG is the gold standard for the evaluation of drowsiness. The Karolinska Drowsiness Score (KDS), proposed by T. Akerstedt is based on a calculation of the proportion of alpha and theta waves per 20s-epoch of EEG [5]. The Objective Sleepiness Scale (OSS), proposed by A. Muzet, is a combination of criteria based on the quantity of alpha and theta activities in the EEG and blink activity [6].

Our objectives were:

- to validate an algorithm for the online measurement of drowsiness based on a single channel only.
- to improve and facilitate the use of the OSS, by proposing guidelines to explicit visual criteria.

II. METHODS

19 volunteers (aged 30 ± 6 years, 12 F) were monitored while driving a car-simulator for 2 hours. The protocol included a Cortical Brain State (CBS) test before each driving session, where subjects maintain eyes closed for 3 minutes. Recorded signals were EEG (C3, O1, P3, Fz, bipolar CzPz, C4O2), EOG, and ECG (Embla S7000). The OSS stood for the visual reference. This scale, based on combined observation of specific EEG patterns and slow blinks and eye closures, defines for each 20s-epoch 5 different states of drowsiness, from OSS0 (no drowsiness sign) to OSS4 (very drowsy) (Table 1).

TABLE I. OSS CRITERIA, FOR EVERY 20S-EPOCH.

OSS Score	EEG content, α and θ cumulative duration	Blinks and eye movements
OSS0	negligible	normal
OSS1	less than 5s	normal
OSS2	less than 5s or less than 10s	slow
OSS3	less than 10s or more than 10s	normal
OSS4	more than 10s	slow

The scale can be simplified by merging states to a define 3-state scale with OSS0-1 (no clear drowsiness), OSS2 (confirmed drowsiness) and OSS3-4 (marked drowsiness). The EEG channel used for automated analysis (AA) is Cz-Pz [7].

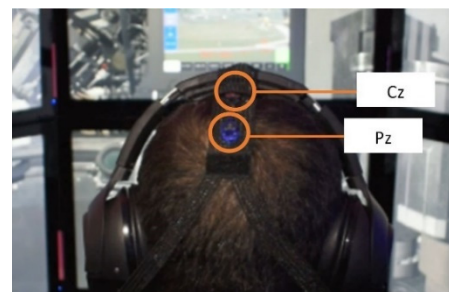


Figure 1: EEG sensor location used by automatic analysis

The recordings, scored by Muzet (AV1) and the automatic analysis (AA), were divided into 2 data sets: DS1 (n=3) aimed at quantifying the impact of changing the scoring criteria; DS2 (n=16) aimed at evaluating inter-scoring variability.

DS1 was analyzed by a second expert VA2, first by applying the literal OSS scoring rules; second, by relying specifically on α , θ and β patterns as they appeared during the calibration phase, i.e. adapting the EEG scoring criteria by taking into account the individual characteristics deriving from the CBS test. The epoch-by-epoch agreement (concordance percentage) was calculated between AA, AV1 and AV2.

III. RESULTS

On DS1, the 5-state / 3-state agreement between AV1 and AV2 increased from 15% / 70% when applying literal rules up to 83% / 96% when applying adapted rules using CBS test as criteria calibration. Table 2 contains the agreements on DS2.

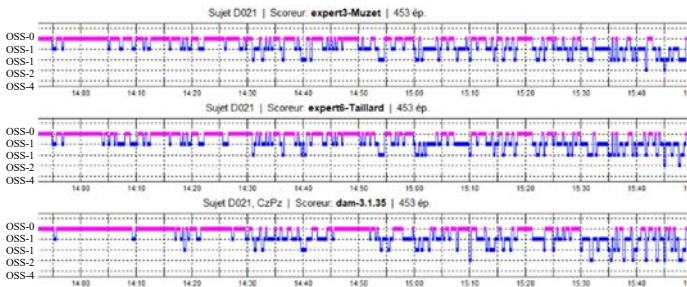


Figure 2: Scoring comparison between AV1 (upper plot), AV2 (middle plot) and AA (lower plot), for on subject of DS2.

TABLE II. AGREEMENTS FOR THE 5- AND THE 3-STATE (BLUE) COMPARISONS

Agreement (%)	5-state	3-state	AV1	AV2	AV1 \cap AV2	AA
AV1				73		72
AV2			88			64
AV1 \cap AV2						79
AA			90	86	94	

IV. DISCUSSION

The comparison results are very good on a simplified 3-state scale, which may be sufficient in terms of drowsiness monitoring in many operational situations. For the full 5-state scale, comparisons shown significant differences (more than 2 states) between visual analyses, showing that the refining the scoring rules is still a work in progress, and justify pursuing this work in further studies. Regarding automatic analysis, comparison against visual consensus showed good results. If the scoring rule evolve, the algorithm will have to comply with these evolutions.

This work allows a key criterion to be explicated, which is the importance of the biocalibration phase, as alpha and theta rhythms used to determine drowsiness states must be defined by their characteristics as they appear during the CBS test.

The ongoing work on visual analysis of drowsiness will help extend this study, especially in various environments. The specific constraint of each operational environment, in terms of

electromagnetic environment and movements, can impact the signal, hence the performance of the algorithm. For validation purposes, comparison to visual analysis remains the gold standard. Therefore, the use of the existing visual scales must be improved and facilitated.

No behavioral elements are integrated in the definition of drowsiness in that perspective. It is clearly distinguished from other phenomenon such as attention or inattention, cognitive workload (or the absence of it) where physiology and behavior are intertwined, and of purely behavioral elements such as performance. The necessary distinction between the two approaches – physiology with drowsiness and behavior with performance – has been highlighted in situations where they were dissociated [8].

In operational conditions, especially from a human factor point of view, performance is the only relevant endpoint.

However, even if drowsiness and behavior (i.e. performance) should be distinguished from a methodological point of view, there is a strong link between them. Decrease in performance can be tracked down to a various range of causes: insufficient skills and competences, inattention, tunneling, boredom... and drowsiness. Conversely, drowsiness does not necessarily translate into degraded performances – but it does so often (see [5]) that the situation where subjects are “sharp and sleepy” appears as an exception. Likewise, we hypothesize that the outcome of other cognitive processes is modulated by the level of drowsiness. Cognitive workload, as the resultant of objective difficulty of the task and individual resources is probably modulated by the level of drowsiness,

It is therefore relevant to assess drowsiness in a probabilistic approach to performance: a drowsy subject increases his/her risk to be non-performant, a non-drowsy subject increases his/her chances to be performant.

ACKNOWLEDGMENT

Work supported by the French Ministry of Defense.

REFERENCES

- [1] Schmidt et al. “Homeostatic Sleep Pressure and Responses to Sustained Attention in the Suprachiasmatic Area”, Science, 324, 516, 2009
- [2] François et al. “Tests of a New Drowsiness Characterization and Monitoring System Based on Ocular Parameters”, Int J Environ Res Public Health. 2016 Jan 29;13(2):174. doi: 10.3390/ijerph13020174
- [3] Dinges et al. “PERCLOS: A valid psychophysiological measure of alertness as assessed by psychomotor vigilance,” US Dept of Transp., Fed. highway Admin. Publication n°FHWA-MCRT-98-006
- [4] Sahayadhas et al. “Drowsiness detection during different times of day using multiple features” Australas Phys Eng Sci Med. 2013 Jun;36(2):243-50. doi: 10.1007/s13246-013-0200-6. Epub 2013 May 30
- [5] Anund et al. “Driver impairment at night and its relation to physiological sleepiness”, Scand J Work Environ Health 2008;34(2):142-150
- [6] Muzet et al. “Preventing driver drowsiness at the wheel: can steering grip sensor measurement contribute to its prediction?” Proc. of 4th Eur. Congress on Intelligent Transport, Budapest, 24-26 May 04
- [7] Berthomier et al., Real-Time Automatic Measure of Drowsiness based on a Single EEG Channel. J. Sleep Res., 17:P434, 2008.
- [8] Galliaud et al. “Sharp and sleepy: evidence for dissociation between sleep pressure and nocturnal performance”. JSR, 2008, 17: 11-15

Application of the Paradigm of Nets-within-Nets to Air Traffic Management

Juan-Ignacio Latorre-Biel

Department of Engineering
Public University of Navarre. Campus of Tudela.
E-31500 Tudela (Spain)
Juanignacio.latorre@unavarra.es

Iñigo Leon-Samaniego, Emilio Jiménez-Macías

Department of Electrical Engineering
University of La Rioja
E-26004 Logroño (Spain)
inigo.leon@gmail.com, emilio.jimenez@unirioja.es

Abstract—Air Traffic Management presents certain challenges that can be faced by the use of modeling and simulation. The approach of nets-within-nets, belonging to the paradigm of the Petri nets, is an appropriate modeling formalism for the dynamics of aircrafts and their interactions. The use of reference nets has been reported to be applied to different environments, such as the challenging task of modeling manufacturing factories in the frame of Industry 4.0. This formalism may describe aircrafts as discrete event dynamic systems that can synchronize between them and with their environment. Simulation can be a powerful tool for detecting potential conflict situations in advance, for identifying feasible decisions in ATM, and for classifying them, regarding the degree in achieving the objectives of the decision makers.

Keywords—component; Petri nets; nets-within-nets; decision making support; UAV

I. INTRODUCTION

Introduction

Petri nets is a modeling paradigm that has been broadly applied to a high diversity of fields, from telecommunications to food industry and from robotics to biology. This paradigm has been enriched with a broad body of theoretical knowledge, while many different classes of Petri nets have been developed for enhancing their applicability in certain fields or for developing a solid theoretical background[1]. Petri nets allow a double representation. On the one hand, they can be described by means of a bipartite oriented graph, which explicitly show the structure of the model, the interrelation between subsystems, and its dynamics through the evolution of its marking. This graphic representation is very intuitive as well as precise and rigorous. As a consequence, it helps in understanding the structure and behavior of the model, while this information can be easily shared between people with different educational and professional backgrounds. On the other hand, Petri nets can be described by a matrix-based formulation, very suitable for computer processing for operations, such as simulation and state space analysis.

The approach of the nets-within-nets leads to formalisms based on the Petri net paradigm, such as reference nets, nested Petri nets, and object nets [2]. These formalisms may contain tokens that are in fact Petri nets themselves or that reference

them. This approach is very powerful, since different autonomous systems can be represented as discrete event dynamical systems by token nets. As a consequence, the autonomous systems, can be characterized by a structure, a current state, as well as a certain behavior that results from the evolution of the state.

Moreover, the context or environment of the token nets can be modelled by a component of these formalisms, which can be called system net.

II. APPLYING THE APPROACH OF THE NETS-WITHIN-NETS TO ATM

In an ATM context, different actors, such as manned aircrafts or unmanned aerial vehicles (UAV), can be modelled by token nets [3]. The communication and synchronization between them may model their negotiation for achieving their objectives, while safely and efficiently sharing the airspace or any other environment, such as an airport [4]. Communication and synchronization of the token nets with the environment, or system net, may model service or operation requests.

A feasible and promising application of models based on the approach of nets-within-nets is simulation [5]. It is possible to study a certain configuration of a region of airspace or of an airport and mimic the behavior of the system until a certain criterion is met. The influence of stochastic events on the evolution of the Petri net may be taken into consideration in the simulation process. In order to provide with robust and reliable results, if enough computational resources and time are available, it is possible to apply Monte Carlo methods.

Based on simulation, it is possible to unfold the state space in the form of a reachability tree. This object, provide with the complete range of states that can be reached by the system, depending on the decisions that can be made along the simulation. These decisions tend to solve the firing priorities of transitions involved in real conflicts.

Having at hand all the feasible outcomes of the decisions made in the frame of an ATM applied to the Petri net model of real system may be a powerful tool for decision making support. However, a large amount of outcomes might make a challenging task the process of choosing one of them. As a

consequence, classifying the feasible decisions may be of great help to the decision makers. An optimization process based on simulation can be carried out to quantify the quality of every solution to the decision problem, regarding a certain criterion. Each decision maker might have different priorities and; hence, specific and diverse criteria [6].

As a result of the previous considerations, each decision maker could have a specific list of the feasible solutions to a decision problem, classified regarding their degree to meet the particular objectives.

The mentioned features of a Petri net, and the particular possibilities that reference nets may offer, allow the modeling of manned and unmanned aircrafts, as well as other characters, such as passengers, in the form of the so called token nets. Token nets populate a system net, model of the context, for example a portion of the airspace or an airport.

The combination of such a model and simulation-based techniques allow tackling problems, such as Aircraft collision avoidance in congested airspace, real time slot reallocation in airports under congestion caused by weather conditions, or the development of a decision support system for conflict

resolution in the frame of Unmanned Aerial System Traffic Management-UTM.

REFERENCES

- [1] Silva, M., "Introducing Petri nets", in F. DiCesare, G. Harhalakis, J. M. Proth, M. Silva, & F. B. Vernadat (Eds.), *Practice of Petri Nets in Manufacturing*. (pp 1-62). Springer, 1993.
- [2] R. Valk, "Object Petri Nets. Using the Nets-within-Nets Paradigm", in J. Desel, W. Reisig, & G. Rozenberg, (Eds.), *Advances in Petri Nets: Lectures on Concurrency and Petri Nets*, volume 3098 of *Lecture Notes in Computer Science*, (pp. 819-848). Springer-Verlag, Berlin, Heidelberg, New York, 2004.
- [3] Charles L. and C. Tessier, "Particle Petri Nets for Aircraft Procedure Monitoring Under Uncertainty", In G. Ciardo and P. Darondeau (Eds.): *ICATPN 2005*, LNCS 3536, pp. 329–348, 2005.
- [4] M. A. Piera, J. J. Ramos, R. Moreno Ortiz, and M. Radanovic, "A Negotiation Mechanism for a Consensus in Air Traffic Conflict Resolution", in *Proceedings of the 2018 International Conference on Advances in Big Data, Computing and Data Communication Systems (icABCD)*. Durban, South Africa.
- [5] J. Skorupski, "Airport Traffic Simulation Using Petri Nets", in J. Mikulski (Ed.): *TST 2013*, CCIS 395, pp. 468–475, 2013.
- [6] N. Schefersa, M. A. Piera, J. J. Ramosa, and J. Nosedal, "Causal Analysis of Airline Trajectory Preferences to Improve Airspace Capacity", in *Proceedings of the ICTE 2016*, December 2016, Riga, Latvia.

What if Controllers would no Longer be Limited by What the Human Eye can See out of the Tower Windows?

Sara Bagassi, Francesca De Crescenzo, Sergio Piastra
University of Bologna
Forlì, Italy

Carlo Alfredo Persiani, Cristian Nativi
ENAV S.p.A.
Italy

Mohamed Ellejmi
EUROCONTROL
France

Alan Ross Groskreutz
CRIDA
Spain

Abstract— RETINA Project deals with Augmented Reality for tower control centers. Specifically, it is a SESAR exploratory research project investigating the applicability of Augmented Reality display techniques for the Air Traffic Control (ATC) service provision by the airport control tower. An overview of the main results of the project is reported in the following extended abstract. The results obtained through the validation of the RETINA concept are fully demonstrating the soundness for the introduction of Augmented Reality in the Airport Control Tower, especially in low visibility conditions (LVC)

Keywords-Augmented Reality, Airport Control Tower, Synthetic Vision

I. INTRODUCTION

RETINA Project deals with Augmented Reality for Tower control centers. Specifically, it is a SESAR exploratory research

project investigating the applicability of Augmented Reality display techniques for the Air Traffic Control (ATC) service provision by the airport control tower.

The study motivation lies in the process of evolution of the airport control towers (Fig.1). With the introduction of automation, the controller sight was progressively pulled away from the out of the tower window view, as the majority of information is available on the head-down interface inside the control tower. This interface affects controllers' workload by forcing them to repeatedly switch their sight between the head-down equipment and the out of the window view.

On the other hand, AR technologies offer the opportunity of moving information from the head-down interface to the head-up view, by means of digital transparent overlays registered to the real environment, similarly to the vision currently provided in the aircraft cockpits with head-up displays.



Figure 1. RETINA motivation and concept

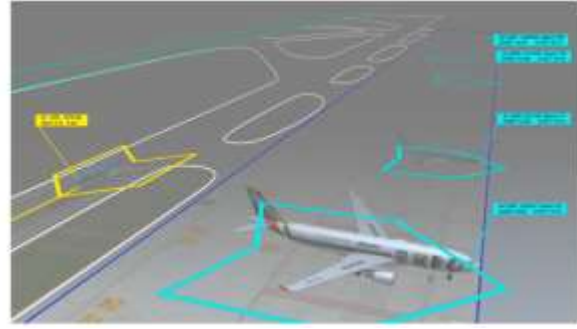
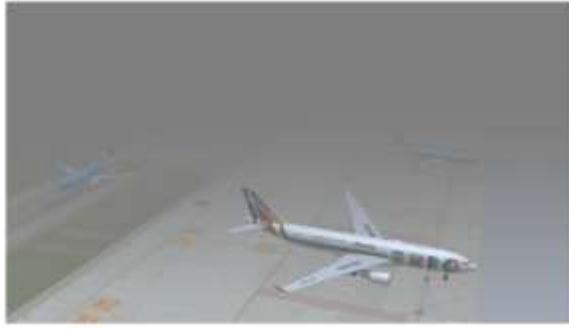


Figure 2. In low-visibility conditions the use of synthetic overlays enhances the ATCO's situation awareness

RETINA Project considers two different Augmented Reality technologies: See-Through Head-Mounted Displays and Spatial Displays (which are large conformal head-up displays that are supposed to coincide with the tower windows).

This choice derives from a selection process where the state of the art of augmented reality display techniques was deeply analysed and evaluated, considering predictions on possible improvements of such devices in the near future as well.

Such technologies provide the placement of additional information over the actual “out of the window view” that the controllers have. The digital overlays superimposed over the physical world are represented in RETINA by flight tags, aircraft bounding boxes, airside layout, runway status, meteorological data and warning detection (Fig.2 shows the comparison between the out of the tower window view without AR overlays and the same one characterized by additional digital data in bad visibility condition).

II. PROJECT OVERVIEW

The project target was to demonstrate the positive impact of the proposed Augmented Reality tools, in terms of human performance (situational awareness and the human factors), safety (the capability to detect some typical hazardous situations such as runway incursions) and efficiency (workload and maintenance of capacity in poor visibility conditions).

In order to pursue this objective, the RETINA concept was validated in a laboratory environment by means of human-in-the-loop real-time simulations involving controllers, who were placed in an immersive 3D virtual environment represented by three rear projected screens, simulating a high-fidelity and photorealistic out of the window view from the Bologna Airport Control Tower (LIPE). The operators were also provided with head-down equipment replicating the current one in the control tower and with a voice communication with a pseudo-pilot post located in a control room, with the role of monitoring and updating the traffic on the airport model according to the clearances given by the controller.

Three different main equipment were considered (Fig.3): a baseline equipment, that is the current way of working in the control tower and two AR equipment: Microsoft HoloLens device (that played the role of Head Mounted Display technology) and superimposed digital overlays inside the

simulated virtual environment, playing the role of the Spatial Displays coinciding with the tower windows.

It was necessary to simulate Spatial Displays via software, as the big formats of this type of technology are not yet on the market nowadays, so that it was not possible to integrate the hardware in the simulation loop. The Spatial Display augmentation was considered for 9 out of 32 Control Tower windows.

The subjects were asked to perform all tasks as Tower and Ground controller during the same exercise, as no distinction of roles between Tower and Ground position was necessary due to the simplicity of the selected airport scenario. The validation exercises were characterized by: two different real observed traffic conditions (medium traffic and medium-high traffic) and three different visibility conditions (from good weather condition to extremely bad one).

For each exercise performed using Augmented Reality tools, a similar exercise was conducted adopting the baseline equipment, in order to compare data obtained in terms of the human performance, safety and efficiency validation targets.

III. RESULTS OVERVIEW

The results obtained through the validation of the RETINA concept are fully demonstrating the soundness for the introduction of Augmented Reality in the Airport Control Tower. Major benefits are related to the use of such technology in low visibility conditions to restore the same level of airport capacity as in normal visibility conditions, with positive impact on the whole ATM system in terms of safety, efficiency and resilience.

In particular, compared to the current tower operations, RETINA tools:

- provide controllers with a unique conformal representation of all the needed information and stimulates controllers to work in a head-up position, increasing situational awareness and safety.
- provide quantified benefits in terms of mental workload, temporal workload, performance, effort, frustration and information accessibility.
- lead to the reduction of the current restrictions due to Low Visibility Procedures, increasing the throughput of the airport.

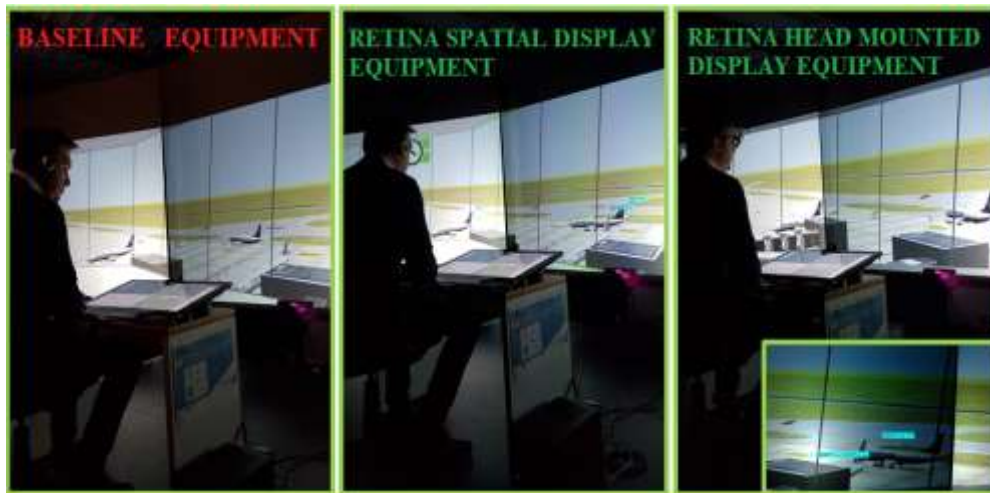


Figure 3. Three different equipment were considered during the RETINA validation: a baseline equipment and two AR equipment, namely Microsoft Hololens device and Spatial Displays.

ACKNOWLEDGMENT

This project has received funding from the SESAR Joint Undertaking under grant agreement No 699370 under European Union's Horizon 2020 research and innovation programme.

REFERENCES

- [1] Ronald J. Reisman, David M. Brown; Design of Augmented Reality Tools for Air Traffic Control Towers; 6th AIAA Aviation Technology Integration and Operations Conference (ATIO), Sept. 2016
- [2] Ellejmi, M.; Bagassi, S.; Piastra, S.; Persiani, C.A.; Evaluation of Augmented Reality Tools for the provision of Tower Air Traffic Control using An Ecological Interface Design; 2018 Modeling and Simulation Technologies Conference, AIAA AVIATION Forum, (AIAA 2018-2939).
- [3] Masotti, N.; Bagassi, S.; De Crescenzo, F. (2016) Augmented Reality for the Control Tower: The RETINA Concept. Augmented Reality, Virtual Reality, and Computer Graphics - Lecture Notes in Computer Science, Springer Verlag, 2016, 9768. pp. 444-452.
- [4] Masotti, N.; De Crescenzo, F.; Bagassi, S., Augmented reality in the control tower: A rendering pipeline for multiple head-tracked head-up displays, Augmented Reality, Virtual Reality, and Computer Graphics - Lecture Notes in Computer Science, Springer Verlag, 2016, 9768, pp. 321 – 338.
- [5] Bagassi, S.; De Crescenzo, F.; Lucchi, F.; Masotti, N. (2016) Augmented and Virtual Reality in the Airport Control Tower. In: 30th Congress of the International Council of the Aeronautical Sciences, Sept 25 - 30, 2016., Daejeon (South Korea).
- [6] De Crescenzo F., Bagassi S., Fantini M., Lucchi F.: Virtual Reality based HUD (Head Up Display) to simulate 3D conformal symbols in the design of future cockpits. Presented at the Council of European Aerospace Societies Conference, Venice, Italy (24-28 October, 2011).
- [7] Sara Bagassi, Francesca De Crescenzo, Francesca Lucchi, Franco Persiani: Innovation in Man Machine Interfaces: Use of 3D Conformal Symbols in the Design of future HUDs (Head Up Displays). In: 28th International Congress of The Aeronautical Sciences, Brisbane, Australia September 23-28 (2012).